# Long-Term Cost-Effectiveness of Housing First for Homeless People with Mental Illness

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## Abstract

**Background.** Homelessness has been expanding in Canada and internationally. It significantly increases mortality and thus is a public health concern. Housing First (HF), an approach that involves providing immediate access to permanent housing and individualized support services, is a key component of strategies to end homelessness. A two-year cost-effectiveness study found that HF resulted in significant cost-offsets but did not fully pay for itself.

**Objective.** The objective of this project was to develop a simulation model to project HFs effects on costs and housing stability, from a societal perspective, compared to treatment-as-usual, over a ten-year horizon.

Approach. A novel Excel-based platform, Discretely Integrated Condition Event (DICE), was used to build a Markov simulation model. Cost and outcome data were ascertained from the Montreal At Home/Chez Soi randomized controlled trial. Individuals were divided into eight subgroups based on need level, homelessness history, and intervention received. Nine possible housing states including street, shelters, psychiatric hospitalization, and prison, were defined. Daily transition probabilities between states were calculated by subgroup. Costs for healthcare, social, and justice services, and income were calculated for each housing state using generalized least squares regression. Days in stable housing was used as the outcome measure. One-way sensitivity analyses were conducted on the discount rate, the rate of "autonomization" for services provided by HF (i.e., the proportion of participants who after the second year need only the rent supplement, but not the support of a clinical support team), and the death rate obtained from outside sources. **Results.** Data from 425 (257 in the HF group and 168 in the TAU group) of the 463 individuals randomized at the beginning of the study were included for analysis. Results indicate that HF is both cost-saving and more effective than treatment as usual (TAU). Over ten years, HF participants averaged an additional 1,501 days in stable housing compared to TAU, while costing \$26,527 less. Individuals who had a longer history of homelessness and higher need level had the largest cost savings. Savings stem from individuals in HF transitioning and staying in HF apartments at a higher rate. TAU groups tend to spend more time in expensive forms of unstable housing such as emergency housing and substance abuse treatment. Housing First continued to be more effective and less costly over plausible ranges of the parameters selected for sensitivity analyses.

**Conclusion.** This model illustrates the differences in effectiveness of HF based on clients' need level and homelessness history. Overall findings suggest long-term cost-effectiveness of HF is even greater than suggested by the two-year findings.

## Résumé

**Contexte.** L'itinérance est en expansion au Canada et à l'étranger. Elle augmente considérablement le risque de mortalité et constitue donc un problème de santé publique. Le logement d'abord (LA), une approche qui consiste à fournir l'accès immédiat à un logement permanent et l'accès à des services de soutien individualisés, est un élément-clé des stratégies pour mettre fin à l'itinérance. Une étude de sa coût-efficacité pendant les deux premières années a conclu que le LA entraînait des compensations de coûts importantes mais n'était pas entièrement rentabilisé.

**Objectif.** L'objectif de ce projet était de développer un modèle de simulation pour projeter les effets de l'approche HF sur les coûts, d'un point de vue sociétal, et la stabilité du logement, en comparaison avec les services habituels, sur un horizon de dix ans.

Approche. Un modèle de simulation de Markov été construit utilisant une nouvelle plateforme, *Discretely Integrated Condition Event (DICE)*, construite avec le logiciel Excel. Les données sur les coûts et les résultats ont été déterminées à partir du site de Montréal de l'essai contrôlé à répartition aléatoire At Home/Chez Soi. Les individus ont été divisés en huit sousgroupes selon le niveau de besoin, les antécédents d'itinérance et le groupe d'intervention. Neuf états de logement possibles, tels que la rue, les abris d'urgence, l'hospitalisation psychiatrique et la prison, ont été définis. Les probabilités quotidiennes de transition entre les états de logement ont été calculées par sous-groupe. Les coûts des soins de santé, des services sociaux et de la justice ainsi que les revenus moyens ont été calculés pour chaque état de logement en utilisant la régression généralisée des moindres carrés. Les jours dans un logement stable ont été utilisés comme mesure d'efficacité. Des analyses de sensibilité ont été menées sur le taux d'actualisation, le taux d' « autonomisation » des services fournis par LA (c'est-à-dire, le pourcentage de participants qui, chaque année après la seconde année, n'ont plus besoin du soutien d'une équipe

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de soutien clinique mais conservent néanmoins leur supplément au loyer) ainsi que le taux de mortalité obtenu de sources extérieures.

**Résultats.** Sur les 463 individus répartis de façon aléatoire, 425 (257 dans le groupe LA et 168 dans le groupe recevant des services habituels, SH) ont fourni des données utilisables. Les résultats indiquent que LA est à la fois moins coûteux et plus efficace que les services habituels (SH). Sur dix ans, les participants LA ont accumulé en moyenne 1,501 jours supplémentaires dans un logement stable de plus que SH, tout en coûtant \$26,572 de moins.. Les personnes qui avaient des antécédents d'itinérance plus longs et des besoins plus élevés ont réalisé les économies les plus importantes. Les économies proviennent des personnes LA se rendant et demeurant dans des appartements LA à un taux plus élevé. Les groupes SH passent généralement plus de temps dans des formes coûteuses de logement instable, comme le logement d'urgence et le traitement de la toxicomanie. Le LA est demeuré plus efficace et moins coûteux sur des plages plausibles des paramètres sélectionnés pour les analyses de sensibilité.

**Conclusion.** Ce modèle illustre les différences d'efficacité de LA en fonction du niveau de besoins des clients et des antécédents de sans-abri. Les résultats globaux suggèrent que le rapport coût-efficacité à long terme de LA est encore plus élevé que ne le suggèrent les résultats sur deux ans.

# **Contribution of Authors**

Hannah Rochon drafted all sections of this thesis and manuscript. Dr. Eric Latimer conceived the thesis topic and acquired the data. Hannah Rochon, Dr. Eric Latimer, and Dr. Dimitra Panagiotoglou contributed to the interpretation of the data, critically revised the thesis, and approved the final version.

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# List of Abbreviations/Acronyms

ACT: Assertive Community Treatment AH/CS: At Home/Chez Soi study AIC: Akaike Information Criterion **DES:** Discrete-Event simulation DICE: Discretely Integrated Condition Event ER: Emergency Room GLM: Generalized linear multivariable HF: Housing First HN: High needs HSJSU: Health, social, and justice service use questionnaire ICER: Incremental cost-effectiveness ratio ICM: Intensive Case Management MN: Moderate needs **RCT: Randomized Control Trial** TAU: Treatment as usual US: United States

VTLFB: Vocational timeline follow-back questionnaire

# 1. Introduction

On any given night an estimated 35,000 Canadians experience homelessness and over the course of a year at least 235,000 Canadians are affected by homelessness.<sup>1</sup> Homelessness is a serious socio-economic challenge that has been expanding in many countries and jurisdictions, including Canada.<sup>2</sup> Those experiencing homelessness face a multitude of hardships including marginalization, exposure to violence, involvement in the criminal justice system, increased rate of mortality, and an increased rate of mental illness and substance use disorders.<sup>3–8</sup> As a result, homeless individuals are frequent users of health, social, and criminal justice services.<sup>5,9</sup> A large randomized control trial (RCT) performed in Canada, At Home/Chez Soi, estimated that each homeless individual with mental illness costs Canadians on average between \$30,000 and \$59,000 annually.<sup>10</sup> Thus, in addition to the desire to alleviate human suffering, ending homelessness can be justified on public health and economic grounds.

As various communities are realizing that emergency responses to homelessness are not remedying the situation, many are beginning to implement Housing First (HF) as part of a strategy to end homelessness.<sup>11</sup> HF is an intervention for individuals experiencing homelessness that is centred on providing immediate access to housing without requiring preparatory steps (e.g. sobriety).<sup>12</sup> Following placement in permanent housing, underlying issues such as mental illness or addiction, are addressed. Numerous RCTs have shown that HF is effective in terms of achieving housing stability.<sup>13–17</sup> Studies also indicate that HF leads to cost offsets from health, social, criminal justice, and housing services, suggesting HF is also a cost-effective intervention.<sup>18–20</sup> However, all current studies are limited by relatively short follow-up periods.

As such, the long-term cost-effectiveness of HF remains unknown and is most relevant to decision-makers.

This thesis projects costs, outcomes, and cost-effectiveness using a two-year data set from the At Home/Chez Soi (AH/CS) study. The rigorously collected AH/CS data set was coupled with a cohort Markov model to create projections. The Markov model was implemented using a novel simulation platform, discretely integrated condition event (DICE), developed specifically for health-economic modelling.<sup>21</sup> DICE offers a flexible and transparent structure for representing the occurrence of events, such as hospitalizations, that influence the evolution of variables, such as housing stability and costs. <sup>22</sup>

As with most economic studies of HF to date, effectiveness will be measured in days of stable housing. The economic analysis will be carried out from a societal perspective, modified to include disability benefits and social assistance. All costs will be presented in 2019 Canadian dollars.

This model provides insight into the long-term resource use and housing stability for individuals participating in HF. Observed patterns, such as the effect of an emergency room visit, on long term costs, were extrapolated. Given that HF has been shown to improve housing stability, this thesis aimed to determine the long-term economic effect of HF to help policymakers make informed decisions.

## 2. Literature review

A literature review was conducted to summarize the current state of homelessness, evidence from Housing First, and provide an overview of simulation models. The goals of this review were to determine an up-to-date definition of homelessness, quantify the current state of homelessness in Canada, determine related health and economic outcomes associated with homelessness, and define the different types of homelessness. Housing First's core principles and randomized controlled trials were identified including participants' information related to housing stability, psychiatric symptoms, substance use, quality of life, and economic data. Literature was scanned and a team from France was contacted to learn about their ongoing related work. Finally, a brief overview of types of simulation models was provided to describe the advantages and disadvantages of each. Relevant studies were found through MEDLINE and reviewing reference lists.

## 2.1 Background on homelessness

How homelessness is defined affects who is included within the homeless classification. The Canadian Observatory on Homelessness proposed the current Canadian definition of homelessness - "a situation of an individual, family or community without stable, permanent, appropriate housing, or the immediate prospects, means and ability of acquiring it".<sup>23</sup> This definition restricts the term 'homeless' to those experiencing "a situation" of not having housing. The province of Quebec's definition goes a step further and highlights important factors that lead to homelessness: A process of social disaffiliation and a situation of social exclusion characterized by a person's difficulty in having a stable, safe, adequate and healthy home due to a lack of housing or his or her inability to maintain one and, at the same time, in maintaining functional, safe and stable relationships in the community. Homelessness is explained by a combination of social and individual factors that constitute the life experience of men and women. <sup>24</sup>

Compared to Canada's, Quebec's broad definition captures more individuals.

Homeless is not necessarily a static state, but often a fluid one that individuals can enter and exit at different times. Consequently, it is more appropriate to view people as 'experiencing homelessness', rather than labelling them 'homeless'.

Homelessness has many causes. Personal risk factors for homelessness include mental and physical illness, low education level, substance abuse, domestic violence and traumatic childhood experiences.<sup>25</sup> In addition, system, social, and economic failures can heighten one's risk of experiencing homelessness. These include a lack of affordable housing, inadequate income, insecure employment, decreased benefit payments, or discrimination.<sup>26</sup> For many individuals, it is the interaction of these personal risk factors with system, social, and economic failures that lead to the onset of homelessness.<sup>23,27</sup>

Over time the demographics of Canadians experiencing homelessness have shifted. Historically, individuals experiencing homelessness were predominantly middle-aged, single, and male.<sup>1</sup> Today a greater diversity of individuals are affected by homelessness. A study that relied on data from Canadian emergency shelters from 2005 to 2014 identified demographics of individuals using shelters in Canada. It found that among shelter users who identify within the gender binary, males made up 72.4% of occupants with an average age of 40 years, while females made up 27.3% and had an average age of 36 years.<sup>28</sup> On one night in 2018 volunteers and researchers surveyed individuals experiencing homelessness in Montreal.<sup>29</sup> Of those surveyed, 75% were male, 23% were female, and 2% identified as having a different gender identity. Those over 65 years of age accounted for 6% of those surveyed while those under 18 years of age accounted for 4%. Aboriginals and Inuit were overrepresented in the sample representing 12% and 2.9% respectively while on the Island of Montreal Aboriginals represent 0.6% of the population and Inuit represent 0.04%. Social assistance was reported by 70% of participants as their primary source of income. While these numbers are not a perfect representation of all individuals experiencing homelessness, they aid in providing a glimpse into the population.

Homelessness can have many impacts on one's health leading to increased service use and costs compared to the general population. It is helpful to break these down into three main categories: health services, justice-related services, and emergency housing services.

#### 2.1.1 Health Services

Homelessness is clearly associated with poor health. Certain health conditions such as mental illness and substance use, can contribute to the onset of homelessness.<sup>25,30,31</sup> Additionally, risk factors for homelessness, such as low socioeconomic status and substance use, are also independent risk factors for ill health.<sup>30,32,33</sup> For individuals experiencing homelessness, crowded shelters, long periods walking and standing, and cold temperatures result in an increased risk of disease, infection, substance misuse, injuries, and mental illness.<sup>27,31,32,34–40</sup>

In countries such as Canada with universal health insurance, key barriers to accessing health care are reduced. However, Canadians experiencing homelessness have a difficult time obtaining and adhering to medical recommendations for physical or mental illnesses.<sup>30,31</sup> Competing needs for food and shelter result in neglecting health treatments and prevention.<sup>41</sup>

When individuals do use the medical system, they tend to do so frequently.<sup>42–44</sup> As individuals experiencing homelessness have an increased propensity for poor health, those individuals who do seek care tend to have greater rates of medical care use compared to the general population.<sup>31,40,42,45–47</sup> They tend to make use of many services including physical and psychiatric hospitalization, emergency room (ER) visits, mental health care, substance use disorder treatment, and outpatient visits.<sup>9,31,45,48</sup> Not surprisingly, a large portion of medical costs stem from mental health and substance misuse treatment as there is a high prevalence of both illnesses among the homeless population.<sup>36,49–55</sup> Those experiencing homelessness tend to seek out the ER not only for medical care, but also for food, shelter, and safety.<sup>56,57</sup> One of the goals of HF is to

offer clients more targeted health care services resulting in more effective and less costly services.<sup>58–60</sup>

#### 2.1.2 Justice-Related Services

Individuals generate costs to society through involvement with the criminal justice system via arrests, court visits, or imprisonment. It is not uncommon for individuals experiencing homelessness to have encounters with the criminal justice system.<sup>5,61,62</sup> A Canadian study of individuals experiencing homelessness found that over a third of participants had been arrested in the previous six months.<sup>10</sup> Since an individual experiencing homelessness does not have a permanent address, they are substantially more likely to be denied bail and remanded into custody when arrested.<sup>44,62</sup> In the US, upwards of 20% of homeless individuals have a history of imprisonment.<sup>61,63,64</sup> Similarly, individuals leaving correctional facilities have an increased risk of housing insecurity.<sup>65</sup> This leads to a cycle, commonly referred to as the 'revolving door' of homelessness and incarceration, in which individuals alternate between homelessness and incarceration.<sup>62,66</sup>

Among individuals experiencing homelessness with mental illness in five Canadian cities, the average annual cost per person for police contacts and court appearances ranged from \$3,491 to \$15,323.<sup>10</sup> The same study reported the annual incarceration costs ranged from \$1,117 to \$6,950 per individual experiencing homelessness.<sup>10</sup> A 2009 Canadian study found that supportive housing, transitional housing, and group homes were less than one-tenth of the cost of incarceration in a provincial correctional facility.<sup>62</sup> Additionally, the longer an individual spends without access to homeless intervention and support programs, the higher their criminal justice

system costs.<sup>44</sup> Supportive housing aims to limit first-time criminal justice encounters and provides discharge plans to ensure incarcerated individuals do not get trapped in the revolving door.

### 2.1.3 Emergency Housing

When an individual is experiencing homelessness, they have few options as to where to sleep. Among these options are emergency shelters, which are available to those who cannot access permanent housing (encompassing youth, men, and women overnight shelters, shelters for those impacted by violence, or shelters for those fleeing natural disasters).<sup>23</sup>

While emergency housing provides short term shelter, it can be harmful to an individual's mental and physical health.<sup>27,67</sup> The risk of contracting various infectious diseases is higher among those living in communal environments, such as shelters.<sup>27,39,68,69</sup> In the 2018 Montreal homelessness count, 43% of individuals who spent the night outside and who had not made use of emergency housing in the past year stated they avoided emergency housing due to fear of bedbugs and other pests, fear for their safety, regulations perceived as excessive, and various discomforts such as smells, noise, and lack of privacy.<sup>70</sup>

Individuals living in shelters tend to also have worse psychiatric symptoms and satisfaction when compared to individuals living in group homes, halfway houses, cooperative apartments, and permanent supportive housing.<sup>67</sup> Decreased satisfaction and worse psychiatric symptoms perhaps stem from the view that shelters further reinforce the marginalized identity of a homeless individual through rules and restrictions.<sup>71</sup> Additionally, shelters are more tolerant and have

lower standards of required behaviour compared to group homes, half-way houses, and cooperative housing. Therefore, while shelters are useful in a crisis, they should not be viewed as a solution to ending homelessness.

The cost per person associated with emergency shelters varies depending on the jurisdiction and services offered. In Canada, the costs of providing one emergency shelter bed, up to three meals, and minimal supports are estimated to cost between \$25 and \$110 per night.<sup>72</sup> The mean annual cost of shelters is estimated to range from \$1,091 to \$6,411 per homeless individual, including those who do not make use of shelters.<sup>10</sup> Without comprehensive services provided by the shelter, additional societal costs stem from social services, psychiatric care, and health service use.

#### 2.1.4 Social Assistance Payments

Government benefits are an integral part of social safety nets. Many forms of government benefits such as welfare, disability support payments, old age security, and employment insurance can be found under the umbrella term "Social Assistance". To be eligible for social assistance, an applicant must meet a strict set of criteria, such as a mandatory three-week job search period or proof of disability, which can lead to the onset of homelessness.<sup>73</sup> The application process also imposes barriers to individuals experiencing homelessness such as the lack of a primary mailing address and documentation, low proficiency in English or French, and difficulty accessing a telephone or internet.<sup>73</sup> Despite these hurdles, social assistance is the primary source of income for many individuals experiencing homelessness.<sup>74</sup> Among individuals participating in the 2018 Montreal homelessness count, 70% reported social assistance as their primary source of income.<sup>29</sup> In five Canadian cities, annual social assistance benefit expenditures ranged from \$6,968 to \$10,887 per individual experiencing homelessness.<sup>10</sup> Without stable housing individuals experiencing homelessness experience difficulty finding and maintaining legal employment.<sup>10</sup>

## 2.2 Types of Homelessness

Individuals can experience different types of homelessness that can be classified according to two dimensions: cross-sectional and temporal. A cross-sectional classification system classifies the types of place a person is staying in at a particular point in time. Using a temporal classification system integrates the person's history and pattern of homelessness (i.e. if they are temporarily, episodically, or chronically homeless). The Canadian Observatory on Homelessness uses a cross-sectional classification system to aid in defining different types of homelessness.<sup>23</sup>

- Unsheltered: individuals who lack shelter and are not accessing emergency shelters.
  These individuals can be found in parks, vacant buildings, cars, tents, or makeshift shelters.
- Emergency sheltered: individuals who cannot access permanent or transitional housing and as such are living in emergency shelters that require no or minimal payment.
   Emergency overnight shelters, individual/family shelters for those impacted by violence, or emergency shelters for those fleeing natural disasters are a few examples.
- 3. Provisionally accommodated: individuals who are without shelter and access forms of housing with no prospect of being permanent. Individuals who are provisionally accommodated may be accessing temporary forms of housing provided by the

government, a not-for-profit, or have independent arrangements for short-term stays. Specific subcategories are:

- a. Interim (or transitional housing): a systems-supported form of housing that aims to bridge the gap between unsheltered or emergency sheltered homelessness and permanent housing. Individuals are typically provided with additional services beyond basic needs, and more privacy. The ultimate goal is to prevent the return to homelessness. Interim housing typically imposes a time limit but generally allows for longer stays (up to three years) than emergency shelters.
- b. Living temporarily with others, but without guarantee of continued residency or immediate prospects for accessing permanent housing: encompasses scenarios where individuals do not have means to secure permanent housing and are staying with friends, family, or strangers. These individuals are typically referred to as 'couch surfers' or the 'hidden homeless'. They typically do not pay rent and their duration of stay is unsustainable for the long-term.
- c. Short term, temporary rental accommodations without security of tenure: describes temporary rental arrangements without the possibility of permanency such as staying in motels, hostels, or rooming houses.
- d. Institutional care with lack of permanent housing arrangements: defines scenarios where individuals lack access to permanent housing upon release from institutional care. Individuals may be staying in penal institutions, medical or mental health institutions, or residential treatment programs.
- e. *Accommodations/reception centers for recently arrived immigrants and refugees:* include arrangements for recently arrived immigrants or refugees and who have

not yet secured their own housing and have no means or prospects of permanent housing. Such individuals receive settlement support and are temporarily housed while orienting to life in Canada.

4. At risk of homelessness: Individuals in housing situations that could potentially be permanent, but who lack security and stability. This includes individuals in precarious employment, suddenly unemployed, on time-limited housing support (such as receiving a housing supplement for up to one year), those facing eviction, those with severe mental illness or substance use disorders or in a violent or abusive household.

While this classification system is beneficial for understanding an individual's experience at a point in time, it can be equally useful to incorporate the individual's history of homelessness. For example, individuals who use time-limited services as long as they are allowed at which point, they move onto new services. These individuals would be classified as provisionally accommodated using the cross-sectional classification system, however, they may benefit from more directed services that aim to break the cycle of homelessness typically provided to those classified as unsheltered.<sup>23</sup> For this reason, some experts have suggested the use of a classification system that incorporates the amount of time an individual experiences homelessness.<sup>75</sup> The usefulness of this way of classifying people experiencing homelessness is further supported through the significance of the time homeless parameter in a Canadian outcome trajectory analysis of homelessness interventions.<sup>76</sup> The incorporation of a time spent homeless parameter in the classification system aids in providing directed housing interventions. Kuhn and Culhane provided initial empirical support for a three-level classification system which incorporated two dimensions: frequency of homelessness and duration of homelessness.<sup>77</sup>

### **Table 1: Temporal Classification System**

|                | Short duration | Long duration |
|----------------|----------------|---------------|
| High Frequency | Episodic       |               |
| Low Frequency  | Transient      | Chronic       |

The number of days to define long versus short duration and high versus low frequency is dependent on the policy or research question being asked.

These two classification systems are both useful and complementary. The cross-sectional system proposed by the Canadian Observatory on Homelessness aids to inform the type of homelessness an individual is experiencing at a specific point-in-time, while the temporal system describes an individual's history of homelessness.

## 2.3 Housing First

Historically, homelessness and its underlying causes have been addressed using a diversity of programs, often organized into a continuum of care. Individuals are intended to move through the programs in a stepwise manner with the end goal of permanent stable housing. However, failure in one aspect, such as sobriety, can result in the loss of current services such as housing. Many studies have shown that for homeless individuals with co-occurring disorders, this bundling of social and housing services threatens the attainment of housing stability.<sup>78–80</sup> As an alternative to the linear treatment system, Housing First (HF) was proposed.<sup>12</sup> HF is an

intervention centred on providing individuals immediate access to permanent housing and individualized support services. In all HF programs, clients should be given choice as to the type and location of housing they receive. All housing options must be adequate (no major repairs required), affordable, and suitable for the composition of the residents.

Two variants of the HF model exist: congregate housing and scattered-site. Congregate housing refers to many units within a building. This single-site scheme allows similar service delivery at a lower cost, avoids the challenge of securing rental properties, and contributes to an increase in affordable housing.<sup>81</sup> The second variant of HF is scattered-site housing and refers to clients housed in rental market apartments in different buildings, with a rent supplement such that each participant contributes a fixed percentage of their income towards rent (often 25% or 30%). When feasible, scattered-site housing should be offered as it is the preferred option by clients and results in the attainment of their own apartment.<sup>12,17,82,83</sup>

In the 1990s, Dr. Sam Tsemberis founded Pathways to Housing in New York. Pathways to Housing is a not-for-profit organization and the originator of the scattered-site HF model. Pathways to Housing aims to end homelessness and views housing as a basic human right. When designing Pathways to Housing, Dr. Tsemberis chose the scattered-site HF allocation scheme as it incorporates the principle of "consumer choice and self-determination". HF teams rent affordable apartments in the community at fair market value. The ultimate goal is to integrate the client into the community and build supports and social networks outside of a treatment setting.<sup>12</sup> From this point onwards, in this thesis, scattered-site HF will simply be referred to as HF. HF is an intervention that provides housing without requiring any preparatory steps and follows five core principles: <sup>84</sup>

- 1. Immediate access to permanent housing
- 2. Consumer choice and self-determination
- 3. Recovery orientation
- 4. Individual and client-driven supports
- 5. Social and community integration

As a means of determining site adherence to scattered-site HF's core principles, a 38-item fidelity scale was developed.<sup>12</sup> Through the HF fidelity scale, studies have found an association between high fidelity ratings, corresponding with strong adherence to HF principles, and clients achieving housing stability.<sup>19,85,86</sup>

In addition to the five core principles, HF programs should also reject the use of screening programs as individual characteristics are poor predictors of clients' success.<sup>12,87</sup> Staff should be compassionate, positive, barrier-free, and have a forward-looking attitude with their clients. Staff must also demonstrate that they are committed to a long-term working relationship with clients geared towards clients' successfully transition from homelessness to stable housing.<sup>12,17</sup>

While enrolled in HF clients are in control of if and when they begin any treatments. Staff must convey that clients are free to discuss symptoms or substance use openly without judgment and

convey that recovery is possible. Abstinence being viewed as an often unrealistic ideal, HF pursues a harm reduction approach. Staff must clearly express that housing is not contingent on a client's success with mental illness or substance use treatment. Similarly, should the client be evicted from their housing, or desire to change housing, other treatments will not terminate and support finding a new home will commence immediately.<sup>12,17</sup>

A few RCTs have been conducted demonstrating that HF is superior compared to other housing interventions in achieving rapid housing stability and improved quality of life.<sup>88–90</sup> HF has been shown to demonstrate a positive to neutral effect on substance use, psychiatric symptoms, quality of life, and functioning. <sup>13,89–92</sup>

On average, individuals with severe mental illness who are experiencing homelessness living within Canada's three largest cities incur costs borne by society of about \$59,000 annually.<sup>10</sup> Through the implementation of targeted Housing First programs, part of this cost can be reduced. One of the goals of HF is to shift service use from costly crisis responses and institutions to targeted and planned services with regular follow-ups.<sup>12</sup> Cost offsets from ER and inpatient stays were consistently reported in a 2015 HF systematic review.<sup>18</sup>

As HF provides individuals with access to immediate permanent housing, it is a natural effect of HF to be associated with a decrease in emergency housing costs.<sup>18</sup> A 2009 Calgary report indicated that supportive and transitional housing had a lower annual cost per person compared to emergency shelters and institutional responses to homelessness such as prisons, and psychiatric hospitals.<sup>93</sup> The effect of HF on encounters with the criminal justice system is less

conclusive. Some studies report HF leads to decreased involvement with the criminal justice system, while others indicate that HF has no effect.<sup>60,94</sup>

In 2008, The Mental Health Commission of Canada teamed with stakeholders and researchers in five Canadian cities to implement a randomized controlled trial of HF called At Home/Chez Soi (AH/CS).

### 2.3.1 The At Home/Chez Soi Trial

The At Home/Chez Soi trial involved 1,158 participants randomized to receive HF and 990 to receive Treatment as Usual (TAU) in Vancouver, Winnipeg, Toronto, Montreal, and Moncton. The full published protocol is available elsewhere.<sup>95</sup> Below is a brief description of the trial's methods.

Individuals were recruited from street outreach or community agencies that serve people experiencing homelessness such as shelters, drop-in centers and mental health teams. Eligible participants were

- 1. legal adults (18 years or older/19 or older in British Columbia)
- experienced absolute homelessness (lack of a regular, fixed, physical shelter such as living outside or in a parked vehicle) or were precariously housed (primary residence is a single room occupancy, rooming house, or hotel/motel; with two or more episodes of being absolutely homeless in the past year)

 living with a mental health disorder with or without a co-occurring substance abuse disorder, determined by DSM-IV criteria on the Mini International Neuropsychiatric Interview (MINI44) at the time of entry

Individuals currently participating in a different assertive community treatment or intensive case management program; who were not a Canadian citizen, landed immigrant, refugee, or refugee claimant; and were relatively homeless, were excluded. "Relatively homeless" designates individuals whose housing does not meet basic minimum standards: living in overcrowded or hazardous conditions, living in transitional housing (e.g. youth or women transitional houses/shelters), or living in long-term institutions.

Once informed written consent was obtained eligible participants were enrolled in the study. Each individual was classified as requiring a high need (HN) or moderate need (MN) level of care based on an algorithm that included diagnosis, service use, and community functioning. Randomization was performed via a computer program using adaptive randomization methods that altered the probability of being assigned to a group based on the number of individuals already assigned to each group. Adaptive randomization allows individuals to be allocated on an ongoing basis while ensuring an even distribution of individuals with pre-specified characteristics in each group.

All individuals randomized to HF received immediate support from a team of housing specialists. Following the scattered-site housing model, housing specialists worked to quickly find participants a suitable apartment in the private market. Participants agreed to pay 25% of

their income towards rent (30% if rent included heat), with the rest of the rent covered by the intervention.

Participants in HF were offered mental health services based on their need level. Individuals who were classified as high need received HF with access to Assertive Community Treatment (ACT). ACT staff included psychiatrists, nurses, and peer specialists among others. The ACT treatment teams were intended to follow a recovery orientation (i.e. embrace the possibility of recovery) and had a 1:8 staff to client ratio in Montreal, 1:10 in other cities.<sup>96</sup> Participants were linked to entire teams and staff were closely involved in participants' hospital admissions and discharges. The teams met daily to discuss cases and were available to participants seven days per week with crisis coverage available 24 hours per day.

Individuals who were classified as moderate need and were randomized to receive HF accessed intensive case management (ICM). ICM was provided by teams of case managers who worked to integrate efforts from multiple agencies. Originally ICM teams had a 1:20 staff to client ratio, but this was later reduced to 1:16 due to greater than expected levels of need. Once the individual was housed, ICM was provided for a minimum of one year and staff accompanied participants to appointments. Participants were linked primarily to one ICM employee and all staff attended monthly case conferences. ICM staff were available to clients seven days per week for 12 hours per day.

Individuals not randomized to HF received treatment as usual. Individuals in this group accessed existing housing and support services already in place in their communities. It was accepted that

some individuals accessed some components of the intervention's model. As the goal was to compare HF against treatments usually available, however, this was viewed as part of the study design.

Once individuals were allocated to an intervention group, individuals were followed for a maximum of two years. In-person interviews occurred at baseline, 6, 12, 18, and 24 months while interviews at 3, 9, 15, and 21 months could be conducted by phone or in person. Due to the nature of the intervention and questions asked, neither participants nor interviewers were blinded.

The type of residence each participant was staying in and dates of moves were recorded using the Residential Follow-Back Time-Line (RTLFB) questionnaire. The Vocational Time-Line Follow-Back (VTLFB) questionnaire collected information such as the participant's work activities, income (both legal and illegal) earned, and social assistance benefits. The Health, Social and Justice Service Use Inventory (HSJSU) measured the frequency of health, social, and justice services used by each participant.

The AH/CS study found that HF was more effective than TAU in housing placement, days spent in stable housing, perceived quality of life, and community functioning. Not surprisingly, the largest improvement in the quality of life scale was the "living" subscale which investigated home and neighbourhood satisfaction. Individuals in the HF intervention also showed greater community functioning with the largest improvement in the "behaviour" and "social skills" subscale. The "behaviour" subscale included items on cooperation with treatment providers,

substance use, and impulse control, while the "social skill" subscale measured ability and willingness to interact with others. <sup>6,14,59</sup>

Cost-effectiveness of HF using the AH/CS two-year results was investigated separately for MN and HN clients. The cost-effectiveness of HF for those with a MN found that individuals in the HF groups were stably housed for an additional 140.34 days and cost an additional \$7,867.73 compared to TAU. This paper concluded that for MN clients there is an 80% chance HF is cost-effective if a decision-maker was willing to pay \$67 per additional night of stable housing, while there is a 100% chance HF is cost-effective if the decision-maker is willing to pay \$100 per additional night of stable housing.<sup>19</sup>. The cost-effective analysis of HF for those with HN found that HF resulted in an additional 151.30 days of stable housing and cost an additional \$6,310.93 compared to TAU. Thus, if the decision maker is willing to pay \$60 per additional night of stable housing there is an 80% change HF for HN clients is cost-effective. At \$100 per additional night of stable housing there is an 80% change HF for HN clients is cost-effective increases to 100%.<sup>20</sup> These cost-effectiveness analyses indicate that funding HF interventions with ICM for MN and with ACT for HN clients is comparable to what societies currently pay for housing in a supportive setting.

While these economic arguments are encouraging for the implementation of HF, the follow-up duration of past studies has been limited. Additional evidence on the long-term cost-effectiveness of HF is needed. For example, a few studies have looked at the effect of housing on employment and income, however the results are inconclusive.<sup>74,97</sup> Through the creation of a model to project costs and benefits arguments for widespread implementation of Housing First can be better framed.

### 2.4 Cost projection models

When a trial cannot be undertaken due to cost, time, or ethical constraints it is possible to construct a model based on known variables. Limitations on trial-based economic decision-making, such as truncated time horizons or minimal comparators, can be overcome with simulation models.<sup>98</sup> By capturing relevant aspects of the situation, a model can present a restricted representation of reality. Currently, several types of simulation models are available to choose from, each with its advantages and disadvantages. Below is a summary of relevant models and their corresponding strengths and weaknesses.

#### 2.4.1 Basic Types of Models used for Economic Analysis

1. **Decision Tree:** a simple directed graph used primarily to describe the effects of costs and outcomes associated with decisions. A series of pathways represents an individual's potential prognosis and costs following an intervention. The expected value and cost of a specific decision can be computed by averaging the outcomes and costs associated with it. By using a decision tree, one must assume that it is appropriate to model the population in the aggregate and that any fractional outcomes are representative of the same proportion of people in the population. One must also assume that individual decisions happen instantaneously and interim results are not needed. In many instances, decision trees can become quite complex and inefficient. Therefore, a decision tree should only be used for relatively simple scenarios. <sup>79–81</sup>



**Figure 1: A Simple Decision Tree** 

2. Markov: a few variants of Markov models exist. Here the focus will be on two main models: Cohort Markov and Markov microsimulation. Both attempt to capture expected outcomes based on a set of exhaustive and mutually exclusive conditions that describe an individual's states. A state can refer to a health state, such as healthy or sick, or a housing state, such as housed or homeless. These states are associated with a set of predetermined probabilities of transitioning from one state to another. Transitions can either be constant over time or time-varying. Markov models constrain individuals to exist in only one state at a time and individuals can only change states at the end of a fixed time interval, referred to as the cycle length. The underlying constraint that transition probabilities are independent of history, known as the Markovian property, is a limiting factor. However, by trading off efficiency, memory can be added to the model. The researcher can then determine if certain groupings of characteristics affect the probability of an event occurring. If many past states and the time spent in states are strong determinants of what happens next, the Markov model can become too complex to be practical.

A cohort Markov model assumes that the population can be modelled in the aggregate. The cohort of individuals in the model begins in a set of starting states and throughout the model transition based on predetermined state transition probabilities. Transition probabilities are determined based on the current states the cohort is in and are not affected by individual characteristics nor past states or events. This allows the researcher to determine what is expected to happen on average within the population.<sup>99,100</sup>

A Markov microsimulation considers one individual at a time. Using Monte-Carlo draws, individual parameters are assigned (e.g. health status, gender, socioeconomic status etc.) based on either actual patient data or the distributions of patient characteristics in a population. The individual begins in a predetermined starting state and transition probabilities typically depend on both the individual's history as well as some individual characteristics.<sup>99,100</sup>

A Markov model should be chosen over decision trees when time-dependent parameters, time-to-event, or repeated events need to be represented. Expected costs can be calculated by summing the costs associated with each state and the length of time spent in a state.<sup>99–104</sup>





Figure 2A: A Simple Cohort Markov Model



Figure 2B: A Simple Microsimulation

3. Dynamic Transmission: through algebraic equations, individuals or groups are related to each other. These models consider interactions from direct and indirect effects and allow risks to be a function of changing parameters. A causal diagram is first created to begin model development, then stock and flow diagrams are created from referencing literature. While stocks represent the limited capacity of a state, flows represent the rates at which stocks are drained and replenished. In the health care field, dynamic models are often used for infectious diseases (e.g. HIV/AID or malaria) as the risk of infection is affected by the changing ratio of infected to healthy individuals. The flow from a non-infected state to an infected state, therefore, depends on individual characteristics, such as vaccination, and group characteristics, such as the introduction of a vaccination campaign.

An important measure is the basic reproduction number which indicates the rate of disease spread. For example, a basic reproduction number of two indicates exponential growth as each infected individual will infect two healthy individuals.
Dynamic transmission models can be individual- or cohort-based, incorporate economic and health outcomes, and be simple or complex representations. By incorporating economic information, such as intervention costs and cost of illnesses, dynamic transmission models can capture the economic effect of diseases and interventions. Dynamic transmission models are especially useful when modelling interventions and policies that aim to reduce the transmission of diseases.

A system dynamics model uses differential equations to represent the flow between stocks. This construct allows changes in parameters that affect risks. When complex interactions between individuals or disease, distinctly non-randomized mixing patterns, or stochastic effects are important, system dynamics models are preferred. On the other hand, deterministic compartmental models use probabilities derived from data to determine the flow between stocks. Any changes in the value of parameters throughout the model do not affect risks. This is useful when the model seeks to represent the average behaviour of a population. All aspects of these models are expressed in terms of equations, time is continuous, and the results expressed in fractions are proportional to individuals in the population. Dynamic models are optimal for modelling scenarios that must take into account shifts in risk. <sup>100,104–106</sup>



Figure 3: A Simple Dynamic Transmission Model

4. Discrete-Event Simulation (DES): is a flexible mathematical model in which entities can interact and compete for resources within a system and potential outcomes for a population are determined. Entities have corresponding attributes, parameters and characteristics, that may be used to determine responses to a given circumstance. The value of attributes, such as age, health status, or costs, can be changed over the course of the model due to events or individual and system interactions. An event is defined as things that happen to an entity or the environment. The time between events is discrete and intervals can occur at random, using fixed time, or a combination. In DES models, events are also mutually exclusive meaning that no two events can occur at the same time. A resource provides service to an entity and these services may require time. Should an entity require a resource and it not be available, the entity may queue for it. These queues can incorporate maximum capacity, triage systems as well as interim periods to be tracked.

Within the context of health care, entities can be individuals or items such as organs. These entities carry information via attributes such as health status, costs, and age. When an event, such as dose changes or trauma, happens to an entity the value of their associated attributes can change. An entity may then seek a resource, such as a clinic, which can either be available, require a queue, or be unavailable. Throughout the entire model, time and costs are tracked and entities interact with each other and the environment, which can change the value of attributes.

DES allows for memory to be incorporated into the model. DES allows for flexible time intervals resulting in no required assumptions of appropriate interval length. As the time to events is data-driven, DES is an optimal choice when patients are exposed to multiple or competing risks. As attributes update throughout the model, DES is also a good choice when changing patient characteristics or disease process need to be considered.

Compared to Markov models, DES models require fewer assumptions at the price of more data to specify the model. A key disadvantage of DES is the requirement of either expensive software or general software with complex error-prone code writing. Additionally, as the number of parameter estimates increases, a more extensive data set is required.<sup>21,99,100,102,107</sup>



Figure 4: A Simple Discrete-Event Simulation Model

## 2.4.2 Discretely Integrated Condition Event

As researchers and policymakers come from many different backgrounds it is useful to create models in well-known and understandable software. Discretely Integrated Condition Event (DICE) is a simple, transparent, and straight forward Excel-based platform for creating health economic models. Conditions are aspects that persist over time, such as illness severity. Events are instantaneous occurrences that have the potential to alter the level of characteristics, such as hospitalization. Conditions must have a pre-specified set of possible levels, then generally, several equations used to determine how the level of a condition changes over time. Events require the modeller to determine when they occur and the resulting list of possible consequences. No restrictions on the number of events that may occur at any given time are imposed and any resulting changes are reflected immediately. The result of specific events or conditions can be stored in special conditions called accumulators. Context conditions, such as discount rates or local currency, can be applied to the entire model.

Within the DICE platform Cohort Markov, Microsimulation Markov, and non-resourceconstrained DES models can be created. DICE allows users to create a model within Excel with an interface that fosters faster model creation and ease of editing, while being less error-prone. The disadvantages of DICE include Excel's slow running time, inability for individuals to interact, and DICE's failure to incorporate resource queues. Additionally, due to DICE being relatively new, few publications attest to its performance.<sup>21,22</sup>

#### 2.4.3 Economic Models of Individuals Experiencing Homelessness

To date, there have been a few Markov models created using data from individuals experiencing homelessness. In 2018 a Markov model was developed using data from 400 homeless adults in St. Louis, Missouri. Over a two-year time horizon, the authors explored the influence of marginalization, substance abuse, and service utilization on the transition between street, shelter, and housed states. They found family support, high routine service use, and moderate emergency service use was associated with a higher probability of moving from sheltered to housed states. Transitioning to the street state was associated with being from out of town, substance use, and having limited social supports. This study reinforces the notion of social and economic supports being consistent positive influences of transitioning to housing states.<sup>108</sup> In 2013, Yoon et al. investigated factors affecting the transition to independent housing using a cohort of homeless individuals enrolled in a community treatment program. They found that those who participated

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in the program without interruption had a significantly greater probability of achieving independent housing. Those diagnosed with depression, personality, or anxiety disorders were more likely to achieve independent living than those diagnosed with schizophrenia or bipolar disorder.<sup>109</sup>

A team in France has been working on a model of Housing First, with a less rich data set than out own, but their results have not yet been published.

#### 2.4.4 Perspective of Economic Analyses

Predetermining the perspective of an economic analysis allows results to be targeted at a particular group.<sup>99,101,110</sup> An intervention that looks unattractive to one group may be of interest to another group. The main perspectives when conducting a health economic analyses include the ministry of health/public health care payer, government, or society.<sup>101</sup> Analyses can also be conducted from other perspectives such as the patient or caregiver.<sup>101</sup> When conducting analyses from the ministry of health's perspective, health and social care costs and expenditures that are borne by the government are assessed.<sup>110</sup> Conducting analyses from the government perspective involves investigating changes in costs including health and social care costs and expenditures that are borne by the government, tax revenue, and government-borne disability benefit payments. Analyses performed from the societal perspective take account of a broad range of costs such as personal income, personal health and social care expenditures, and government-borne disability does not include costs such as tax revenue, government-borne disability payments, and private disability payments as these are considered transfer payments. It is possible to modify costs and

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expenditures investigated under each perspective.<sup>110</sup> Modifying perspectives are typically done when analyses are specifically targeting certain groups of individuals.

## 2.5 Summary

This review has provided some general information on homelessness, the Housing First model, associated costs, and relevant modelling approaches. A Canadian and a Quebec definition of homelessness were reviewed as well as demographics of Canadian individuals experiencing homelessness.

To better understand the costs associated with homelessness, costs were broken down into three sections: medical, criminal justice, and housing services. Individuals experiencing homelessness have an increased risk of mortality and morbidity. Resource use and costs for medical care are higher among individuals experiencing homelessness than the general population. Homeless individuals also incur costs to society through justice system involvement including arrests, imprisonment, or court visits. The concept of the costly revolving door between homelessness and incarceration was also introduced. Finally, costs associated with emergency housing as well as their associated effect on mental and physical health was summarised.

Two complementary classification systems for individuals experiencing homelessness were described. A cross sectional classification system provides important information on an individual's current situation while a temporal classification system aids in understanding individuals' history of homelessness.

Housing First, a homelessness intervention that focuses on providing immediate access to housing, was introduced as well as its five core principles. The importance of providers adhering to HF's key concepts and the effect of adherence on housing outcomes was highlighted. At Home/Chez Soi was a Canadian study on HF that was conducted from 2009 to 2013. This study found that HF leads to housing stability, improved quality of life and increased community functioning. Cost reductions through the implementation of HF via the substitution of HF for other costly services such as shelters, jails, or ER visits were explored.

While evidence suggests HF leads to cost reduction, the studies from which these arguments were based all have a limited follow-up time. As such, there is a need to create a projection model to gain a better understanding of the long-term costs and benefits of HF. Relevant projection models and their strengths and weaknesses were covered. Depending on the desired output, available data, model complexity, statistical coding ability, and access to statistical programs an appropriate model can be determined.

This literature review has demonstrated the public health and economic hurdles associated with homelessness. Without the implementation of effective homelessness interventions, homelessness will continue to affect Canadians and the economy. Through the creation of a projection model, policymakers will be better equipped to form evidence-based arguments of scarce resource allocation for future homeless interventions.

# 3. Study Objectives

The primary objective of this thesis was to investigate the long-term costs and effects of HF for individuals with mental illness. The secondary objective was to assess how baseline participant characteristics alter the cost-effectiveness. The model was coded using the DICE platform to allow policymakers and researchers from different backgrounds to readily understand how the model operates.

This thesis takes a step towards bridging the knowledge gap between short term and long-term effects of HF. A more complete picture is created to depict how HF, and participants' baseline characteristics, affect costs and housing stability in the long-term. This will allow communities to create more targeted programs aimed at reducing the proportion of people experiencing homelessness. Researchers will also have a better idea of HF's long-term effects, and perhaps, fuel a motivation to run a long-term study.

# 4. Methods

## 4.1 Preface

To achieve our objectives, a cohort Markov model was developed using data from the Montreal At Home/Chez Soi study. The methods and results of this thesis are presented in one manuscript. Both objectives are addressed in this manuscript.

Additional tables and figures included as supplementary material for the manuscript are found in appendices immediately following the manuscript. A detailed description of the methods regarding the computation of the death rate, regression used to estimate costs, and computation of HF costs follow.

## 4.2 Manuscript

# Long-term Cost-Effectiveness of Housing First for Homeless People with Mental Illness

Word count:

Abstract: 255

Manuscript: 3,494 (excluding references, tables and figures)

**Abbreviations:** ACT, Assertive Community Treatment; AH/CS, At Home/Chez Soi; ER, emergency room; HF, Housing First; HN, high needs; HSJSU, health, social, and justice service use; ICER, incremental cost-effectiveness ratio; ICM, Intensive Case Management; MN, moderate needs; TAU, treatment as usual; VTLFB, vocational timeline follow-back

#### Abstract:

**Background:** Homelessness is a significant public health concern that impacts countries across the globe. Housing First (HF), an approach that involves providing immediate access to permanent housing and individualized support services, is a key component of strategies to end homelessness. Previous cost-effectiveness studies have found that while HF leads to significant cost offsets, it does not completely pay for itself.

**Objective:** To create a cohort Markov simulation model to project HF's effects on costs, from a societal perspective, and housing stability, over a 10-year horizon.

**Methods:** Cost and outcome data from the Montreal At Home/Chez Soi randomized controlled trial were used. Based on need level, homelessness history, and intervention group, individuals were divided into eight cohorts. Nine possible housing states including street, shelters, psychiatric hospitalization, and prison, were defined. Daily transition probabilities between states were calculated by cohort. Costs for healthcare, social and justice services, and income were calculated for each housing state using generalized least squares regression. Days in stable housing was used as the outcome measure.

**Results:** Results indicate that HF is both cost-saving and more effective than treatment as usual (TAU). Over ten years, HF participants averaged an additional 1,501 days in stable housing compared to TAU. Individuals who had a longer history of homelessness and higher need level had the largest cost savings. Overall findings suggest that HF dominates TAU in the long-term.

**Conclusion:** Based on these results, expanding HF programs appears to be merited from an economic standpoint.

## Introduction

In Canada, over 35,000 individuals are estimated to experience homelessness on any given night.<sup>1</sup> Housing First (HF), an intervention that provides immediate access to permanent housing and individualized support services, has proven to be an effective program to respond to chronic homelessness.<sup>2,3</sup> Various studies have shown that HF is more effective than alternative treatments at achieving housing stability. The limited information on HF's cost-effectiveness suggests that HF leads to cost offsets, but does not pay for itself.<sup>4,5</sup> However, all previous economic studies of HF have been restricted to a follow-up time of two years or less, thus limiting assessments of long-term costs and effects. In response, the objective of this analysis was to determine if HF could be cost-saving in the longer term. To answer this question, a simulation model was developed to project HF's effects on costs, and estimate cost-effectiveness using housing stability as the outcome measure, over a ten-year horizon.

## Methods

## Setting

This model was constructed using data from the Montreal portion of the At Home/Chez Soi (AH/CS) trial.<sup>6</sup> AH/CS was a large randomized control trial conducted in five Canadian cities assessing the effectiveness of HF compared to treatment as usual (TAU).<sup>6–10</sup> Data collection was carried out from October 2009 through June 2013 with each participant followed for a maximum of 24 months. <sup>6–10</sup> In Montreal, 463 individuals experiencing homelessness with a comorbidity of a mental disorder were randomized.<sup>6</sup> Below is a brief summary of AH/CS. The published protocol of AH/CS is available elsewhere.<sup>11</sup>

### AH/CS Participants

Participants were referred from various community agencies serving people experiencing homelessness or recruited via street outreach teams. Individuals in Montreal were eligible if they were above 18 years of age; classified as absolutely homeless or precariously housed with more than two previous episodes of absolute homelessness (lacking regular fixed, physical shelter for more than seven nights with little prospects of attainting shelter in the next month) in the previous year; and had a mental disorder with or without a co-occurring substance use disorder. Individuals were not eligible if they were receiving services from a separate Intensive Case Management (ICM) team or Assertive Community Treatment (ACT) team as these services are similar to those provided by the intervention (minus the housing supplement).

Eligible participants completed a comprehensive intake questionnaire and were assessed as having either high or moderate needs. High-need (HN) participants had a Multnomah Community Ability Scale score less than or equal to 62; a Mini-International Neuropsychiatric Interview diagnosis of bipolar disorder or psychotic disorder; and one of: (1) comorbid substance use, (2) two or more hospitalizations for mental illness within one year in the previous five years, or (3) one or more arrests or incarcerations in the past six months. Otherwise, individuals were classified as having moderate need (MN).

#### Intervention

Individuals randomized to HF received assistance with finding and keeping an apartment from a team of housing specialists. The intervention included a rent subsidy set so that the participant paid 25% of their income towards rent (30% in cases where heat was included in the rent).

Those randomized to HF and classified as HN received the support of an ACT team comprised of a psychiatrist, one or more nurses, a peer specialist and other professionals. ACT teams worked to provide clients with comprehensive, community-based treatment, rehabilitation and support.<sup>12</sup> Alternatively, HF participants with MN received the support of an ICM team comprised of case managers. Case managers delivered rehabilitation services directly and brokered access to other services.<sup>13</sup> Both the ACT and ICM teams were intended to deliver their interventions in a recovery-oriented manner.<sup>14,15</sup>

All other participants received treatment as usual (TAU). Clients in the TAU condition had access to existing community-based housing and support services including rehabilitation services (e.g. transitional housing, and drug and alcohol rehabilitation centers), as well as emergency response services, such as shelters and hospitals.

#### Measures

As part of follow-up, participants completed the Residential Time-Line Follow-Back questionnaire every three months.<sup>16</sup> This questionnaire asked participants to construct a timeline of their move-in and move-out dates during the previous three months. Individuals were then classified as staying in one of 34 different types of places. For our model, we grouped these 34

places into nine categories: street, temporary housing, emergency housing, substance abuse treatment, psychiatric hospitalization, hospitalization for physical reasons, prison, permanent housing, and Housing First apartments. Unlike previous AH/CS analyses, places that imposed a maximum length of stay greater than six months were classified as temporary rather than stable housing. Stable housing thus included both rent-subsidized apartments that the HF program helped participants obtain and any other types of housing with no time limit (e.g., some supportive housing). This restrictive definition of permanent housing is more consistent with definitions used in Canadian, especially Quebec's, point-in-time homelessness counts.<sup>17,18</sup>

Information on the frequency of health, social, and justice services was captured by the Health, Social and Justice Service Use (HSJSU) questionnaire. The HSJSU was developed for the AH/CS study and was completed by participants every six months. The questionnaire collected information on the frequency of non-overnight health, social, and justice-related services. Information on participants' income (both legal and illegal) was elicited by the Vocational Time-Line Follow-Back (VTLFB) questionnaire every three months.<sup>19</sup>

## Perspective of the economic analysis

We estimated costs using a societal perspective, modified to include disability benefits and social assistance costs.<sup>20</sup> Costs were inflated to 2019 dollars using the city-specific all-item consumer price index.<sup>21</sup>

#### Modelling Approach

We used a cohort Markov model with a cycle length of one day. Costs and days of stable housing, the outcome measure, were aggregated over a ten-year (3,650 days) time horizon. The model was implemented using a novel simulation platform, Discretely Integrated Condition Event (DICE) in Microsoft Excel.<sup>22</sup>

To assess the effects of baseline demographics, individuals were classified into distinct cohorts. Based on previous research, hypothesis testing was used to determine if participant need level, homelessness history, and gender predicted health, social and justice services costs net of earned income.<sup>19</sup> As gender did not emerge as significantly associated with this aggregate nonresidential cost, the sample was then classified into eight cohorts based on: (1) each participant's need level (HN or MN); (2) whether at baseline the participant had been homeless for two or more years, or less; and (3) whether the participant was in the Housing First or TAU group.

Using the imputed two-year dataset, transition matrices were calculated for each of the eight cohorts. Previous work found individuals in the HF group had a higher rate of transition into housing during the first year of the intervention.<sup>6</sup> Therefore, daily transition matrices were calculated separately for each month (30 days) of the first year for HF cohorts. The second year of HF participant data was used to calibrate the daily transition matrix for the remainder of the model. As participants in the TAU group did not experience significant changes in their services following entry into the study, the full two-year dataset was used to determine the daily transition matrix for each of the TAU cohorts and applied to the ten-year model.

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As described below, we estimated a cost per day for each nightly location, including the costs of housing as well as those of health, social, and justice-related costs, net of legally earned income. Costs and the number of individuals in each nightly location were recorded at the end of each daily cycle and aggregated over ten years. Days of stable housing was used as the outcome measure.

#### Costing

Costs were divided into two types: residential costs and service use net of income earned. With the exception of costs associated with the intervention, all costs were derived from a past study.<sup>20</sup> Daily transition probabilities used in our model required that we convert all costs into daily costs.

The residential cost of each housing category was calculated separately for each cohort. For eight categories of housing (all except HF apartments) costs were calculated by multiplying unit costs by a weighted average based on the relative frequencies of nightly locations.

The cost per day associated with providing the HF intervention was not available, therefore, a similar approach using weighted averages was followed. The total two-year cost of providing HF rent supplements and the cost of services provided by ICM or ACT teams were aggregated over the two years then divided by the total days in HF apartments. Average daily cost of providing HF rent supplements and ICM or ACT teams were estimated separately.

The average cost of ambulatory health, social, and justice services, including social assistance benefits net of legally earned income, associated with a night in each type of place, was estimated using a two-step process. First, for each individual, this total cost during the two-year follow-up was computed by multiplying frequencies collected by the HSJSU questionnaire by their corresponding unit costs.<sup>20</sup> Second, using a generalized linear regression model, this total cost was regressed against the frequencies of each of the nine types of nightly location for that individual during the two-year period. Hypothesis testing was used for additive and multiplicative interactions at the 0.05 and 0.1 significance level respectively, to determine, for each type of place, whether this cost depended on need level, homelessness history, or group assignment (HF or TAU). Once significant interaction terms were determined, Gaussian and Gamma distributions were tested in combination with identity and log links. The AIC criterion was used to determine the optimal combination of distribution and link.

#### Outcome

As is the case with many HF studies, effectiveness was measured in days of stable housing. Individuals in either permanent housing or a HF apartment were classified as stably housed. All other types of housing were considered unstable.

## Treatment of missing data

For our model, individuals who were missing more than 120 consecutive days of the type of place stayed were excluded from the analysis. For all remaining participants, we used the Amelia package in R to perform multiple imputation (40 iterations) to fill in missing daily places of stay data.<sup>23</sup> The Amelia package allowed imputation of a categorical variable and for previous and subsequent locations to influence those missing. Using random sampling, one of the imputations was randomly selected for each individual on each day.

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Missing data for health, social services (including ACT, ICM, and HF rent supplement), justice services costs and income was estimated using multiple imputations with chained equations (20 imputations) performed in Stata 16.

## Death Rate

Given the short follow-up time of the Montreal AH/CS study, probability of death for an individual at a particular time was estimated using two other data sources: the average death rate in the Toronto AH/CS six-year extension study, and the 2018 Canadian general population death rates.<sup>24,25</sup> Evidence indicates that individuals experiencing homelessness have health vulnerabilities such that their death rate is equivalent to that of individuals in the general population who are about 15 years older.<sup>26,27</sup> This was used to generate linear death rate equations for each cohort accounting for an increased probability of death with older age. The intercept was determined by ensuring the average death rate for the first six years of each cohort was equal to the total average death rate in the Toronto extension study. The daily death rate was converted to a daily probability of death using the following formula<sup>28</sup>:

Daily probability of death =  $1 - e^{-(\text{daily death rate})}$ 

#### Discounting

We assumed individuals in the HF group would continue to receive the same housing supplement for the entire ten-year period. All costs and days in stable housing were discounted annually after the first year, using a rate of 1.5% for the base case scenario, as recommended by the Canadian Agency for Drugs and Technologies in Health.<sup>29</sup>

#### Autonomization rate

Assuming that in time individuals in HF would require lower levels of care, we reduced the cost per day associated with ACT and ICM teams– which we call the "autonomization rate" – by 2.5% annually after the first two years. Costs associated with providing individuals HF apartments were held constant throughout the model.

#### Sensitivity Analyses

Sensitivity analyses were performed to estimate how robust results were to uncertain parameters. Following best practice recommendations, discount rates of 0% and 3% were tested. <sup>29</sup> Values of 0% and 5% were used for the autonomization rate.

Finally, a sensitivity analysis was performed on the linear death rate equation. A 95% confidence interval for the six-year Toronto death rate was calculated to adjust the intercept. The slope was adjusted by increasing the baseline age of each cohort by 10 and 20 years.

#### Ethics

Ethics approval for Montreal's primary data collection was obtained by the Douglas Research Center and from the Center for Addiction and Mental Health, where the AH/CS coordinating center was based.<sup>11</sup> No additional ethics approval was deemed necessary for this modelling study.

# Results

Of the 463 individuals originally randomized, 8.00% of HF participants and 8.35% of TAU participants were omitted due to more than 120 consecutive days of missing nightly locations. Two additional HF participants were omitted as they were incorrectly classified as staying in HF apartments prior to randomization. This resulted in 425 participants who provided usable data. Table 1 provides descriptive statistics for each of the eight cohorts at baseline.

## Costs of each housing state

Costs for the type of location people were staying in ranged from \$0 on the street to \$1,038 in physical hospitalization (supplementary table 2 appendix).

In general, temporary housing and substance use treatment were more expensive for TAU cohorts than their HF counterparts (supplementary table 2 appendix). However, the costs of HF apartments even without including ACT or ICM services were greater than the cost of TAU permanent housing. HF cohorts all had higher costs of emergency housing reflecting a preponderance of staying in ER and crisis housing more than emergency shelters.

Costs of health, social and justice services, and of social assistance net of earned income

The only significant interaction was needs level interacted with spending a night in the street state. Results indicate that when individuals are both HN and staying on the street their daily cost

is significantly smaller than being HN and not staying on the street or staying on the street and being MN (Figure 1).

HN individuals staying in locations other than the street had higher costs of health, social, and justice services, and social assistance net of earned income (supplementary table 3 appendix). Health, social and justice services cost net of earned income for MN individuals ranged from \$35.86 in substance abuse treatment to \$127.33 in the street state. HN individuals' health and services cost net of earned income ranged from \$64.43 in substance abuse treatment facilities to \$115.45 in the prison state.

### **Model Results**

Overall the HF intervention dominated TAU (Table 2). HF dominated two cohorts comprised of individuals who were MN and homeless less than two years and HN and homeless longer than two years. In contrast, the middle cohorts, HN and homeless less than two years (ICER \$36.40) and MN and homeless longer than two years (ICER \$16.82), indicated that HF was more effective at achieving stable housing, albeit at a greater cost than TAU. The aggregated ICER indicates HF is cost saving because there are proportionally more HF individuals in the cost-saving cohorts (59% of HF participants) than in non-cost-saving cohorts.

Participants in HF cohorts transition into HF apartments quickly and a high proportion of individuals remained housed (Figure 1). Conversely, a smaller proportion of TAU participants transitioned into permanent housing, but those who did also remained in permanent housing.

For both HF and TAU, the costliest cohorts were HN and homeless longer than 2 years who spent proportionally more time in high-cost housing states (e.g. prison, emergency housing).

#### Sensitivity analyses

The results of the one-way sensitivity analyses (Figure 2), show the robustness of results to changes in discounting, autonomization rate, and death rate assumptions. Results were very robust to changes in the discount rate and death rate. Changing the autonomization rate of ACT and ICM services had a significant effect on the ICER, but HF remained dominant.

# Discussion

To the best of our knowledge, this is the first study investigating the long-term cost-effectiveness of HF. Consistent with short-term HF studies, HF was more effective at stably housing participants.<sup>24</sup> Results from this model indicate that there will always be a portion of the population experiencing homelessness, however, HF is more effective at achieving stable housing for a higher proportion of individuals.

Participants classified as MN averaged lower overall costs than HN cohorts for both HF and TAU interventions. Surprisingly, HN individuals on the street had lower costs of health, social, and judicial services net of income earned than MN participants. This stems from MN participants spending fewer nights on average in the street than HN participants while having higher total two-year costs for health, social, and justice services net of income earned. Greater savings occurred in models with larger rates of ACT and ICM autonomization. The autonomization rate used in this model was conservative based on the results from an AH/CS extension study conducted in Toronto.<sup>24</sup> After six years of follow-up, 60% of HF participants in Toronto continued to require mental health support services. Thus, the Toronto extension study had an autonomization rate of 40% over 6 years. However, this rate is calculated using a denominator that includes individuals who died and were lost to follow-up. Assuming the Toronto group knew the services used by all individuals lost to follow-up, then the annual rate of autonomization over the 6-year Toronto study is about 7%. Thus, the rates of autonomization of 0%, 2.5%, and 5% used here are still below the annual rate implied by the Toronto extension study, suggesting that cost savings may have been underestimated.

This model highlighted how cost-effectiveness varies by subgroup indicating baseline demographic differences had an effect on cost-effectiveness. Contrary to short-term HF randomized control trials which indicated HF was more effective at housing individuals at a higher cost, this model indicated that HF dominated TAU for MN participants who were homeless for less than two years as well as HN participants who were homeless longer than two years.<sup>4,5</sup>

Cost savings for the less extreme cohort (MN and less than two years homeless) stem from individuals spending proportionally more time in temporary housing which has an associated daily cost of \$124.71. The daily cost associated with staying in an HF apartment for the comparison HF group was \$75.27.

Over ten years, the difference in costs between the TAU and HF group are compounded resulting the large cost-savings observed for the HF group at ten years. Individuals who were HN and had experienced homelessness for longer than two years benefited from receiving more directed services leading to spending less time in costly forms of housing.

This does not mean societies will save costs only when providing HF to cohorts where HF dominated TAU. Even among cohorts where cost-effectiveness was lowest, the cost per additional night of stable housing remained lower than the cost of a night in a shelter. Thus, providing HF to all adults experiencing chronic homelessness with mental illness is warranted from an economic perspective.

# **Strengths and Limitations**

As with any model, the results presented are limited by the appropriateness and accuracy of the model and its parameters. Sensitivity analyses investigated the role of variability and uncertainty in the model parameters and indicated results were robust, thereby improving the generalizability of results. By categorizing participants into eight distinct cohorts and grouping housing states into nine groups, it is possible that some cost or transition estimates biased the results and underlying trends were missed. However, as with any model, we cannot exclude the possibility that we have not modelled some unknown variables. This model benefitted from a very large and highly detailed dataset. This allowed for the model to be run using daily transitions which increased the accuracy of modelling individuals experiencing homelessness.

While this large dataset provided many details regarding participants, death rate data was attained from Statistics Canada and an extension study of AH/CS in Toronto. This pooling of data from multiple sources creates uncertainty in the death rate and in turn, results from the model. However, the Toronto homeless population and services available are similar to Montreal.<sup>30,31</sup> Additionally, the death rate attained from statistics Canada was scaled up to represent health vulnerabilities of individuals experiencing homelessness.

Finally, while this model was constructed using carefully estimated unit costs and meticulously collected frequency of service use it is possible that results are not transferable across jurisdictions.

# Conclusion

Our model demonstrates the potential for HF to be cost-saving in the long-term. It illustrated differences in the effectiveness of HF based on clients' need level and homelessness history. Overall, results indicate that HF is more effective at achieving and maintaining housing stability and is cost-saving in the long term. Thus, by reallocating current funds to aid those experiencing homelessness with severe mental illness, societies could achieve a greater proportion of success in housing individuals, while saving money in the long term. In turn, societies could take a step towards ending, rather than managing, homelessness.

|                                    | MN & homeless < |         | HN & homeless $< 2$ |            | MN & homeless $\geq 2$ |         | HN & homeless $\geq 2$ |         |
|------------------------------------|-----------------|---------|---------------------|------------|------------------------|---------|------------------------|---------|
|                                    | 2 years         |         | years               |            | years                  |         | years                  |         |
|                                    | HF              | TAU     | HF                  | TAU        | HF                     | TAU     | HF                     | TAU     |
| No. (% in                          | 98              | 38      | 21                  | 34         | 85                     | 55      | 53                     | 41      |
| treatment group                    | (38%)           | (23%)   | (8%)                | (20%)      | (33%)                  | (33%)   | (21%)                  | (24%)   |
| Average Age                        | 45.61           | 46.76   | 37.32               | 39.38      | 46.82                  | 45.52   | 40.93                  | 42.57   |
| (Years)                            | (11.3)          | (9.2)   | (10.9)              | (10.8)     | (8.8)                  | (9.5)   | (10.8)                 | (10.3)  |
| <b>Country of Birth</b>            |                 |         |                     |            |                        |         |                        |         |
| Other                              | 17              | 2       | 3                   | 3          | 5                      | 10      | 12                     | 11      |
|                                    | (17.3%)         | (5.3%)  | (14.3%)             | (8.8%)     | (5.9%)                 | (18.2%) | (22.6%)                | (26.8%) |
| Canada                             | 81              | 36      | 18                  | 31         | 80                     | 45      | 41                     | 30      |
|                                    | (82.7%)         | (94.7%) | (85.7%)             | (91.2%)    | (94.1%)                | (81.8%) | (77.4%)                | (73.2%) |
| Gender                             |                 |         |                     |            | • • •                  |         | • • •                  |         |
| Male                               | 58              | 25      | 11                  | 30         | 52                     | 39      | 42                     | 29      |
|                                    | (59.2%          | (65.8%) | (52.4%)             | (88.2%)    | (61.2%)                | (70.9%) | (79.2%)                | (70.7%) |
| Female                             | 40              | 13      | 10                  | 4 (11.8%)  | 32                     | 16      | 11                     | 12      |
|                                    | (40.8)          | (34.2)  | (47.6%)             | <b>x</b> , | (37.6%)                | (29.1%) | (20.8%)                | (29.3%) |
| Transsexual                        | 0               | 0       | 0                   | 0          | 1 (1.2%)               | 0       | 0                      | 0       |
| Marital Status                     |                 |         |                     |            |                        |         |                        |         |
| Single or never                    | 62              | 32      | 21                  | 33         | 64                     | 36      | 40                     | 35      |
| married                            | (63.3%)         | (84.2%) | (100%)              | (97.1%)    | (75.3%)                | (65.5%) | (75.5)                 | (85.4%) |
| Married or                         | 0               | 0       | 0                   | 0          | 0                      | 1       | 1                      | 0       |
| cohabitating                       |                 |         |                     |            |                        | (1.8%)  | (1.9%)                 |         |
| Divorced or                        | 35              | 6       | 0                   | 1          | 21                     | 16      | 12                     | 6       |
| separated                          | (35.7%)         | (15.8%) |                     | (2.9%)     | (24.7%)                | (29.1%) | (22.6%)                | (14.6%) |
| Widowed                            | 1               | 0       | 0                   | 0          | 0                      | 2       | 0                      | 0       |
|                                    | (1.0%)          | -       |                     | -          | -                      | (3.6%)  | -                      | -       |
| Self-identified ethnoracial status |                 |         |                     |            |                        |         |                        |         |
| Yes                                | 15              | 2       | 3                   | 4          | 4                      | 9       | 12                     | 11      |
|                                    | (15.3%)         | (5.3%)  | (14.3%)             | (11.8%)    | (4.7%)                 | (16.4%) | (22.6%)                | (26.8%) |
| No                                 | 83              | 36      | 18                  | 30         | 81                     | 46      | 41                     | 30      |
|                                    | (84.7%)         | (94.7%) | (85.7%)             | (88.2%)    | (95.3%)                | (83.6%) | (77.4%)                | (73.2%) |
| Education <sup>1</sup>             |                 |         |                     |            | ()                     | ()      |                        |         |
| Less than high                     | 36              | 20      | 12                  | 21         | 48                     | 23      | 31                     | 20      |
| school                             | (36.7%)         | (52.6%) | (57.2%)             | (61.8%)    | (56.5%)                | (41.8%) | (58.5%)                | (48.8%) |
| Completed                          | 23              | 6       | 5                   | 5          | 18                     | 13      | 7                      | 10      |
| high school                        | (23.5%)         | (15.8%) | (23.8%)             | (14.7%)    | (21.2%)                | (23.6%) | (13.2%)                | (24.4%) |
| Some                               | 39              | 12      | 4                   | 8          | 19                     | 19      | 15                     | 11      |
| postsecondary                      | (39.8%)         | (31.6%) | (19.0%)             | (23.5%)    | (22.3%)                | (34.5%) | (28.3%)                | (26.8%) |
| school                             | (22.00.0)       | (2      | (                   | ()         | ()                     | (       | (======)               | ()      |
| education                          |                 |         |                     |            |                        |         |                        |         |

# Table 1: Baseline Demographics for each Cohort (Beginning)

| Mental Health Disorder <sup>2</sup>         |            |             |         |         |          |         |         |         |  |
|---|------------|-------------|---------|---------|----------|---------|---------|---------|--|
| Major depressive e                          | episode    |             |         |         |          |         |         |         |  |
| Yes   | 32         | 15          | 3       | 4       | 20       | 17      | 4       | 6       |  |
|   | (32.7%)    | (39.5%)     | (14.3%) | (11.8%) | (23.5%)  | (30.9%) | (7.5%)  | (14.6%) |  |
| No  | 66         | 23          | 18      | 30      | 65       | 38      | 48      | 35      |  |
|   | (67.3%)    | (60.5%)     | (85.7%) | (88.2%) | (76.5%)  | (69.1%) | (90.6%) | (85.4%) |  |
| Manic or hypomanic episode                  |            |             |         |         |          |         |         |         |  |
| Yes   | 13         | 5           | 3       | 5       | 10       | 7       | 5       | 7       |  |
|   | (13.3%)    | (13.2%)     | (14.3%) | (14.7%) | (11.8%)  | (12.7%) | (9.4%)  | (17.1%) |  |
| No  | 85         | 33          | 18      | 29      | 75       | 48      | 47      | 34      |  |
|   | (86.7%)    | (86.8%)     | (85.7%) | (85.3%) | (88.2%)  | (87.3%) | (88.7%) | (82.9%) |  |
| Post-traumatic stress disorder              |            |             |         |         |          |         |         |         |  |
| Yes   | 3          | 1           | 0       | 1       | 4        | 0       | 0       | 1       |  |
|   | (3.1%)     | (2.6%)      |         | (2.9%)  | (4.7%)   |         |         | (2.4%)  |  |
| No  | 95         | 37          | 21      | 33      | 81       | 55      | 52      | 40      |  |
|   | (96.9%)    | (97.4%)     | (100%)  | (97.1%) | (95.3%)  | (100%)  | (98.1%) | (97.6%) |  |
| Panic disorder                              |            |             |         |         |          |         |         |         |  |
| Yes   | 3          | 1           | 0       | 0       | 5        | 2       | 2       | 1       |  |
|   | (3.1%)     | (2.6%)      |         |         | (5.9%)   | (3.6%)  | (3.8%)  | (2.4%)  |  |
| No  | 95         | 37          | 21      | 34      | 80       | 53      | 50      | 40      |  |
|   | (96.9%)    | (97.4%)     | (100%)  | (100%)  | (94.1%)  | (96.4%) | (94.3%) | (97.6%) |  |
| Mood disorder with psychotic features       |            |             |         |         |          |         |         |         |  |
| Yes   | 1          | 3           | 1       | 1       | 0        | 2       | 2       | 4       |  |
|   | (1.0%)     | (7.9%)      | (4.8%)  | (2.9%)  |          | (3.6%)  | (3.8%)  | (9.8%)  |  |
| No  | 97         | 35          | 20      | 33      | 85       | 53      | 50      | 37      |  |
|   | (99.0%)    | (92.1%)     | (95.2%) | (97.1%) | (100%)   | (96.4%) | (94.3%) | (90.2%) |  |
| Psychotic disorder                          |            |             |         |         |          |         |         |         |  |
| Yes   | 20         | 5           | 14      | 21      | 15       | 10      | 30      | 19      |  |
|   | (20.4%)    | (13.2%)     | (66.7%) | (61.8%) | (17.6%)  | (18.2%) | (56.6%) | (46.3%) |  |
| No  | 78         | 33          | 7       | 13      | 70       | 45      | 22      | 22      |  |
|   | (79.6%)    | (86.8%)     | (33.3%) | (38.2%) | (82.4%)  | (81.8%) | (41.5%) | (53.7%) |  |
| Substance use and                           | dependence | related pro | oblems  |         | <u> </u> | · · ·   |         |         |  |
| Yes   | 57         | 25          | 17      | 25      | 48       | 32      | 38      | 28      |  |
|   | (58.2%)    | (65.8%)     | (81.0%) | (73.5%) | (56.5%)  | (58.2)  | (71.7)  | (68.3%) |  |
| No  | 39         | 13          | 4       | 8       | 35       | 22      | 15      | 12      |  |
|   | (39.8)     | (34.2%)     | (19.0%) | (23.5%) | (41.2%)  | (40.0%) | (28.3)  | (29.3%) |  |
| Alcohol use and dependence related problems |            |             |         |         |          |         |         |         |  |
| Yes   | 30         | 11          | 7       | 8       | 17       | 16      | 19      | 10      |  |
|   | (30.6%)    | (28.9%)     | (33.3%) | (23.5%) | (20.0%)  | (29.1%) | (35.8%) | (24.4%) |  |
| No  | 68         | 27          | 14      | 26      | 68       | 39      | 34      | 31      |  |
|   | (69.4%)    | (71.1%)     | (66.7%) | (76.5%) | (80.0%)  | (70.9%) | (64.2%) | (75.6%) |  |

# Table 1: Baseline Demographics for each Cohort (End)

1. Two Participants in dataset recorded education as "I don't know"

2. Some percentages do not equal 100 due to no response from participants

| Cohort                |     | Average 10<br>year cost per<br>person | Average<br>days in<br>stable<br>housing over<br>10 years per<br>person | Difference<br>in Cost | Difference<br>in Days of<br>Stable<br>Housing | ICER           | Number of<br>people in the<br>cohort |
|-----------------------|-----|---------------------------------------|--|-----------------------|---|----------------|--------------------------------------|
| MN &                  | HF  | \$504,206.90                          | 2539.60  | -\$2,950.53           | 1501.12                                       | UE             | 98                                   |
| 2 years               | TAU | \$507,157.43                          | 1038.48  |                       |   | HF<br>Dominant | 38                                   |
| HN &                  | HF  | \$705,455.90                          | 2502.93  | \$56,137.81           | 1542.10                                       |                | 21                                   |
| 2 years               | TAU | \$649,318.09                          | 960.83   |                       |   | 36.40          | 34                                   |
| MN &                  | HF  | \$503,511.67                          | 2431.66  | \$26,990.38           | 1604.54                                       |                | 85                                   |
| nomeless ≥<br>2 years | TAU | \$476,521.29                          | 827.12   |                       |   | 16.82          | 55                                   |
| HN &                  | HF  | \$736,029.99                          | 1761.42  | -<br>\$53 462 49      | 1197.03                                       |                | 53                                   |
| 2 years               | TAU | \$789,492.48                          | 564.39   | φυυ, 102.49           |   | HF<br>Dominant | 41                                   |
|                       | HF  | \$568,229.31                          | 2340.42  | -<br>\$26 572 24      | 1502.55                                       | UE             | 257                                  |
| I able All            | TAU | \$594,801.55                          | 837.87   | φ20,072.24            |   | HF<br>Dominant | 168                                  |

Table 2: Ten-Year Costs and Housing Stability for the Base Case Scenario



## Figure 1: Daily Cost of Health, Social, and Justice-Related Services Net of Earned Income for High Needs and Moderate Needs Clients









0.00



1500 Days 2000

0.00

1500 Days2000



Figure 3: Tornado Diagram for the Sensitivity Analyses

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Appendix- Supplementary Tables and Transition Matrices

| Type of place people stayed in | Subcategories of the type of    | Unit Cost (per night) <sup>1,2</sup> |
|--------------------------------|---------------------------------|--------------------------------------|
| Model                          | place people stayed in AH/CS    |                                      |
|                                | dataset                         |                                      |
| Street                         | Indoor public space             | 0                                    |
|                                | Bus or subway                   | 0                                    |
|                                | Abandoned building              | 0                                    |
|                                | Car or private vehicle          | 0                                    |
|                                | On the street                   | 0                                    |
| Temporary                      | Hotel/motel                     | 0                                    |
|                                | Own room single occupancy       | 20                                   |
|                                | Own room single occupancy       | Female: \$144                        |
|                                | (with supports)                 | Male: \$95                           |
|                                | Single room occupancy of        | 0                                    |
|                                | another person                  |                                      |
|                                | On room in rooming house (no    | 20                                   |
|                                | support)                        |                                      |
|                                | Own room in boarding house      | 20                                   |
|                                | (typically meals included)      |                                      |
|                                | Apartment or house of           | 0                                    |
|                                | parents/guardian/protector      |                                      |
|                                | (temporary)                     |                                      |
|                                | Apartment or house of another   | 0                                    |
|                                | family member (temporary)       |                                      |
|                                | Apartment or house of another   | 0                                    |
|                                | person                          |                                      |
|                                | House in a group home or foster | \$20                                 |
|                                | family (temporary)              |                                      |
|                                | Transitional housing            | \$72                                 |
|                                | Halfway house                   | \$106                                |
| Permanent                      | Own apartment                   | 0                                    |
|                                | Apartment or house of           | 0                                    |
|                                | parent/guardian/protector       |                                      |
|                                | Apartment or house of another   | 0                                    |
|                                | family member (long term)       |                                      |
|                                | Apartment or house of another   | 0                                    |
|                                | person (long term)              |                                      |
|                                | House in a group home or foster | \$20                                 |
|                                | family (long term)              |                                      |
|                                | Social housing with community   | \$51                                 |
|                                | support                         |                                      |
|                                | Eldercare                       | \$219                                |
|                                | Psychiatric rehabilitation      | \$75                                 |

# Supplementary Table 1: Type of Places People Stayed and Associated Unit Costs (Beginning)

# Supplementary Table 1: Type of Places People Stayed and Associated Unit Costs (End)

| Emergency                   | Emergency room              | \$350  |
|-----------------------------|-----------------------------|--|
|                             | Emergency shelter (with     | \$59   |
|                             | dormitories)                |  |
|                             | Crisis housing              | \$301  |
|                             |                             | Dollard Cormier Institute <sup>3</sup> : \$558 |
| Substance Abuse treatment   | Detox centre                | \$127  |
|                             |                             | Dollard Cormier Institute <sup>3</sup> : \$404 |
|                             | Residential program for     | \$127  |
|                             | treatment or recovery of    | Dollard Cormier Institute <sup>3</sup> : \$404 |
|                             | drug/alcohol abuse          |  |
| Psychiatric Hospitalization | Hospital (psychiatric unit) | \$597  |
|                             | Psychiatric hospital        | \$637  |
| Physical Hospital           | Hospital (medical)          | \$990  |
| Prison                      | Police detention cell       | \$271  |
|                             | Provincial jail             | Men: \$158                                     |
|                             | -                           | Women: \$192                                   |
|                             | Federal penitentiary        | \$365  |
| Housing First Apartment     | HF apartment                | \$34.86 - \$36.11                              |

1. All unit costs presented in 2016 Canadian Dollar

2. Source of unit costs: Latimer EA, Rabouin D, Cao Z, et al. Costs of services for homeless people with mental illness in 5 Canadian cities: a large prospective follow-up study. *Can Med Assoc J Open*. 2017;5(3):E576-E585. doi:10.9778/cmajo.20170018

3. Dollard Cormier is an addiction rehabilitation centre located in Montreal that, being part of the institutional sector, costs more per day than community non-profits

| Cohort        |     | Street | Temporary           | Emergency | Substance<br>Abuse<br>Treatment | Physical<br>Hospital | Psychiatric<br>Hospital | Prison   | Permanent<br>(other<br>than HF) | HF<br>apt. | HF<br>ACT or<br>ICM |
|---------------|-----|--------|---------------------|-----------|---------------------------------|----------------------|-------------------------|----------|---------------------------------|------------|---------------------|
| MN & homeless | HF  | \$0    | \$33.08             | \$105.28  | \$136.76                        | \$1,038              | \$239.99                | \$652.87 | \$8.62                          | \$36.11    | \$39.16             |
| < 2 years     | TAU | \$0    | \$61.20             | \$80.65   | \$195.13                        | \$1,038              | \$302.76                | \$646.57 | \$7.63                          | -          | -                   |
| HN & homeless | HF  | \$0    | \$5.24 <sup>2</sup> | \$102.49  |                                 | \$1,038              | \$172.24                | \$635.00 | \$15.27                         | \$34.63    | \$96.41             |
| < 2 years     | TAU | \$0    | \$49.55             | \$67.02   | \$154.24                        | \$1,038              | \$166.24                | \$654.04 | \$41.11                         | -          | -                   |
| MN & homeless | HF  | \$0    | \$41.01             | \$79.78   | \$168.11                        | \$1,038              | \$199.57                | \$631.67 | \$4.68                          | \$35.01    | \$32.58             |
| > 2 years     | TAU | \$0    | \$47.56             | \$81.32   | \$151.95                        | \$1,038              | \$190.93                | \$644.22 | \$31.70                         | -          | -                   |
| HN & homeless | HF  | \$0    | \$22.97             | \$111.38  | \$171.94                        | \$1,038              | \$166.69                | \$638.46 | \$7.60                          | \$34.86    | \$106.67            |
| > 2 years     | TAU | \$0    | \$46.08             | \$75.81   | \$237.71                        | \$1,038              | \$208.57                | \$638.04 | \$39.63                         |            | -                   |

# Supplementary Table 2: Nightly Residential Costs of Each Cohort

1. cost for all states aside from street and physical hospitalization are calculated using weighted averages dependent on relative frequencies of subcategories

2. costs are lower for this group as individuals tend not to stay in single room occupancy with supports

# Supplementary Table 3: Regression Results for Estimate Average Nightly Cost of Associated Health, Social (excluding ICM and ACT), and Justice Services, and Social Assistance Net of Earned Income

| Type of place people<br>stayed | Coef.    | Lower<br>CI | Upper<br>CI |
|--------------------------------|----------|-------------|-------------|
| Constant (street) <sup>1</sup> | 121.4362 | 88.76496    | 154.1075    |
| Temporary                      | -60.8684 | -95.8235    | -25.9133    |
| Permanent                      | -74.7469 | -109.029    | -40.4646    |
| Emergency                      | -42.5712 | -80.831     | -4.31138    |
| Substance Abuse                | -87.236  | -133.538    | -40.9335    |
| Treatment                      |          |             |             |
| Psychiatric                    | -74.1715 | -119.557    | -28.7864    |
| Hospitalization                |          |             |             |
| Physical Hospitalization       | -53.3943 | -146.883    | 40.09481    |
| Prison                         | -38.5722 | -81.1694    | 4.024896    |
| HF apt.                        | -72.8748 | -105.788    | -39.9616    |
| $HN^1$                         | 27.2504  | 19.826      | 34.67481    |
| Street*HN                      | -59.0022 | -107.673    | -10.331     |

1. coefficient and confidence interval values divided by 720 to reflect daily cost

#### **Supplementary Tables 4: Transition matrices for days 365-720:**

- probability of transitioning from row state (starting state) to column state
- all succeeding years use the same transition matrix with an altered probability of death (and survival)

|                                | Street | Temporary | Permanent | Emergency | Substance Abuse | Psychiatric     | Physical        | Prison | HF     | Death  |
|--------------------------------|--------|-----------|-----------|-----------|-----------------|-----------------|-----------------|--------|--------|--------|
|                                |        |           |           |           | treatment       | Hospitalization | Hospitalization |        | apt.   |        |
| Street                         | 46.67% | 6.67%     | 3.33%     | 13.33%    | 6.67%           | 3.33%           | 0.00%           | 0.00%  | 20.00% | 0.0016 |
| Temporary                      | 0.05%  | 73.74%    | 3.68%     | 3.63%     | 1.24%           | 1.92%           | 0.62%           | 1.55%  | 13.57% | 0.0016 |
| Permanent                      | 0.09%  | 1.89%     | 87.71%    | 1.59%     | 0.64%           | 1.09%           | 0.26%           | 0.78%  | 5.94%  | 0.0016 |
| Emergency                      | 0.20%  | 6.50%     | 6.80%     | 50.64%    | 2.27%           | 3.74%           | 1.58%           | 3.35%  | 24.93% | 0.0016 |
| Substance Abuse<br>treatment   | 0.00%  | 4.88%     | 2.86%     | 3.33%     | 75.95%          | 1.55%           | 0.24%           | 1.19%  | 10.00% | 0.0016 |
| Psychiatric<br>Hospitalization | 0.31%  | 2.90%     | 4.15%     | 4.46%     | 1.56%           | 69.92%          | 0.73%           | 2.28%  | 13.69% | 0.0016 |
| Hospitalization – somatic      | 0.81%  | 10.48%    | 8.06%     | 7.26%     | 6.45%           | 6.45%           | 13.71%          | 6.45%  | 40.32% | 0.0016 |
| Prison                         | 0.00%  | 2.26%     | 2.68%     | 3.03%     | 0.85%           | 1.27%           | 0.64%           | 81.51% | 7.76%  | 0.0016 |
| HF apartment                   | 0.02%  | 1.00%     | 1.04%     | 0.97%     | 0.36%           | 0.51%           | 0.21%           | 0.49%  | 95.39% | 0.0016 |
| Death                          | 0.00%  | 0.00%     | 0.00%     | 0.00%     | 0.00%           | 0.00%           | 0.00%           | 0.00%  | 0.00%  | 100%   |

## Supplementary Table 4A: Transition matrix for MN, homeless < 2 years, HF

## Supplementary Table 4B: Transition matrix for MN, homeless <2 years, TAU

|                   | Street | Temporary | Permanent | Emergency | Substance Abuse | Psychiatric     | Physical        | Prison | Death   |
|-------------------|--------|-----------|-----------|-----------|-----------------|-----------------|-----------------|--------|---------|
|                   |        |           |           |           | treatment       | Hospitalization | Hospitalization |        |         |
| Street            | 92.12% | 1.77%     | 1.63%     | 2.72%     | 0.54%           | 0.14%           | 0.00%           | 1.09%  | 0.0016% |
| Temporary         | 0.10%  | 96.43%    | 1.15%     | 1.06%     | 0.30%           | 0.38%           | 0.22%           | 0.37%  | 0.0016% |
| Permanent         | 0.13%  | 1.27%     | 95.62%    | 1.34%     | 0.54%           | 0.30%           | 0.20%           | 0.60%  | 0.0016% |
| Emergency         | 0.46%  | 2.43%     | 2.37%     | 92.42%    | 0.82%           | 0.56%           | 0.38%           | 0.54%  | 0.0016% |
| Substance Abuse   | 0.37%  | 6.58%     | 9.87%     | 4.75%     | 73.13%          | 1.10%           | 1.65%           | 2.56%  |         |
| treatment         |        |           |           |           |                 |                 |                 |        | 0.0016% |
| Psychiatric       | 0.47%  | 5.44%     | 7.33%     | 8.75%     | 2.60%           | 71.39%          | 0.95%           | 3.07%  |         |
| Hospitalization   |        |           |           |           |                 |                 |                 |        | 0.0016% |
| Hospitalization – | 0.59%  | 3.54%     | 3.35%     | 4.53%     | 0.59%           | 1.57%           | 84.65%          | 1.18%  |         |
| somatic           |        |           |           |           |                 |                 |                 |        | 0.0016% |
| Prison            | 0.25%  | 3.10%     | 2.29%     | 1.80%     | 0.87%           | 0.80%           | 0.43%           | 90.46% | 0.0016% |
| Death             | 0.00%  | 0.00%     | 0.00%     | 0.00%     | 0.00%           | 0.00%           | 0.00%           | 0.00%  | 100%    |

|                                | Street | Temporary | Permanent | Emergency | Substance Abuse | Psychiatric     | Physical        | Prison | HF apt. | Death   |
|--------------------------------|--------|-----------|-----------|-----------|-----------------|-----------------|-----------------|--------|---------|---------|
|                                |        |           |           |           | treatment       | Hospitalization | Hospitalization |        |         |         |
| Street                         | 88.73% | 1.41%     | 0.00%     | 5.63%     | 0.00%           | 0.00%           | 1.41%           | 1.41%  | 1.41%   | 0.0020% |
| Temporary                      | 0.19%  | 72.32%    | 2.73%     | 4.29%     | 1.56%           | 1.95%           | 1.36%           | 1.36%  | 14.23%  | 0.0020% |
| Permanent                      | 0.18%  | 2.36%     | 88.09%    | 1.64%     | 0.55%           | 1.00%           | 0.27%           | 0.82%  | 5.09%   | 0.0020% |
| Emergency                      | 0.24%  | 4.39%     | 4.88%     | 74.39%    | 0.24%           | 3.17%           | 0.98%           | 1.22%  | 10.49%  | 0.0020% |
| Substance Abuse<br>treatment   | 0.00%  | 16.22%    | 27.03%    | 2.70%     | 2.70%           | 0.00%           | 2.70%           | 8.11%  | 40.54%  | 0.0020% |
| Psychiatric<br>Hospitalization | 0.00%  | 3.50%     | 1.87%     | 1.64%     | 0.23%           | 84.58%          | 0.70%           | 1.17%  | 6.31%   | 0.0020% |
| Hospitalization –<br>somatic   | 0.00%  | 13.04%    | 8.70%     | 6.52%     | 8.70%           | 2.17%           | 28.26%          | 4.35%  | 28.26%  | 0.0020% |
| Prison                         | 1.64%  | 6.56%     | 11.48%    | 6.56%     | 3.28%           | 3.28%           | 0.82%           | 50.00% | 16.39%  | 0.0020% |
| HF apartment                   | 0.02%  | 1.25%     | 1.17%     | 0.90%     | 0.28%           | 0.58%           | 0.28%           | 0.56%  | 94.96%  | 0.0020% |
| Death                          | 0.00%  | 0.00%     | 0.00%     | 0.00%     | 0.00%           | 0.00%           | 0.00%           | 0.00%  | 0.00%   | 100%    |

Supplementary Table 4C: Transition matrix for HN, homeless < 2 years, HF

# Supplementary Table 4D: Transition matrix for HN, homeless < 2 years, TAU

|                   | Street | Temporary | Permanent | Emergency | Substance Abuse | Psychiatric     | Physical        | Prison | Death   |
|-------------------|--------|-----------|-----------|-----------|-----------------|-----------------|-----------------|--------|---------|
|                   |        |           |           |           | treatment       | Hospitalization | Hospitalization |        |         |
| Street            | 96.70% | 0.68%     | 0.68%     | 0.87%     | 0.12%           | 0.56%           | 0.00%           | 0.37%  | 0.0020% |
| Temporary         | 0.25%  | 94.67%    | 1.59%     | 1.82%     | 0.44%           | 0.39%           | 0.31%           | 0.54%  | 0.0020% |
| Permanent         | 0.17%  | 1.47%     | 95.54%    | 1.13%     | 0.39%           | 0.52%           | 0.21%           | 0.56%  | 0.0020% |
| Emergency         | 0.29%  | 2.25%     | 2.40%     | 92.88%    | 0.64%           | 0.62%           | 0.20%           | 0.71%  | 0.0020% |
| Substance Abuse   | 0.12%  | 1.22%     | 0.83%     | 1.07%     | 95.58%          | 0.63%           | 0.20%           | 0.36%  |         |
| treatment         |        |           |           |           |                 |                 |                 |        | 0.0020% |
| Psychiatric       | 0.05%  | 1.68%     | 2.05%     | 1.74%     | 0.53%           | 93.11%          | 0.32%           | 0.53%  |         |
| Hospitalization   |        |           |           |           |                 |                 |                 |        | 0.0020% |
| Hospitalization – | 0.52%  | 7.73%     | 7.73%     | 6.70%     | 2.58%           | 3.61%           | 69.59%          | 1.55%  |         |
| somatic           |        |           |           |           |                 |                 |                 |        | 0.0020% |
| Prison            | 0.23%  | 4.51%     | 4.06%     | 3.16%     | 1.24%           | 1.13%           | 0.56%           | 85.10% | 0.0020% |
| Death             | 0.00%  | 0.00%     | 0.00%     | 0.00%     | 0.00%           | 0.00%           | 0.00%           | 0.00%  | 100%    |

|                   | Street | Temporary | Permanent | Emergency | Substance Abuse | Psychiatric     | Physical        | Prison | HF apt. | Death   |
|-------------------|--------|-----------|-----------|-----------|-----------------|-----------------|-----------------|--------|---------|---------|
|                   |        |           |           |           | treatment       | Hospitalization | Hospitalization |        |         |         |
| Street            | 94.66% | 0.85%     | 0.43%     | 0.43%     | 0.21%           | 0.43%           | 0.00%           | 0.43%  | 2.56%   | 0.0016% |
| Temporary         | 0.15%  | 81.92%    | 2.93%     | 2.38%     | 0.92%           | 1.03%           | 0.92%           | 1.06%  | 8.69%   | 0.0016% |
| Permanent         | 0.18%  | 2.66%     | 83.89%    | 2.77%     | 0.60%           | 1.42%           | 0.39%           | 1.10%  | 6.99%   | 0.0016% |
| Emergency         | 0.16%  | 5.60%     | 5.68%     | 63.34%    | 1.40%           | 2.64%           | 1.24%           | 2.55%  | 17.38%  | 0.0016% |
| Substance Abuse   | 0.00%  | 4.31%     | 4.31%     | 3.08%     | 76.12%          | 1.54%           | 0.46%           | 0.46%  | 9.71%   |         |
| treatment         |        |           |           |           |                 |                 |                 |        |         | 0.0016% |
| Psychiatric       | 0.32%  | 6.02%     | 5.07%     | 3.80%     | 2.54%           | 64.03%          | 1.58%           | 3.17%  | 13.47%  |         |
| Hospitalization   |        |           |           |           |                 |                 |                 |        |         | 0.0016% |
| Hospitalization – | 0.28%  | 3.88%     | 3.32%     | 3.88%     | 1.11%           | 0.28%           | 67.59%          | 2.49%  | 17.17%  |         |
| somatic           |        |           |           |           |                 |                 |                 |        |         | 0.0016% |
| Prison            | 0.83%  | 10.40%    | 6.24%     | 4.99%     | 1.87%           | 2.49%           | 0.62%           | 51.56% | 21.00%  | 0.0016% |
| HF apartment      | 0.03%  | 1.04%     | 0.90%     | 1.04%     | 0.31%           | 0.48%           | 0.24%           | 0.50%  | 95.48%  | 0.0016% |
| Death             | 0.00%  | 0.00%     | 0.00%     | 0.00%     | 0.00%           | 0.00%           | 0.00%           | 0.00%  | 0.00%   | 100%    |

Supplementary Table 4E: Transition matrix for MN, Homeless ≥ 2 years, HF

## Supplementary Table 4F: Transition matrix for MN, Homeless ≥ 2 years, HF

|                   | Street | Temporary | Permanent | Emergency | Substance Abuse | Psychiatric     | Physical        | Prison | Death   |
|-------------------|--------|-----------|-----------|-----------|-----------------|-----------------|-----------------|--------|---------|
|                   |        |           |           |           | treatment       | Hospitalization | Hospitalization |        |         |
| Street            | 97.11% | 0.76%     | 0.43%     | 1.12%     | 0.12%           | 0.10%           | 0.21%           | 0.14%  | 0.0016% |
| Temporary         | 0.37%  | 95.07%    | 1.55%     | 1.55%     | 0.51%           | 0.36%           | 0.27%           | 0.33%  | 0.0016% |
| Permanent         | 0.10%  | 1.66%     | 94.99%    | 1.20%     | 0.50%           | 0.49%           | 0.31%           | 0.75%  | 0.0016% |
| Emergency         | 0.52%  | 1.43%     | 1.30%     | 95.32%    | 0.33%           | 0.45%           | 0.30%           | 0.36%  | 0.0016% |
| Substance Abuse   | 0.44%  | 2.33%     | 2.52%     | 1.89%     | 90.64%          | 0.87%           | 0.53%           | 0.78%  |         |
| treatment         |        |           |           |           |                 |                 |                 |        | 0.0016% |
| Psychiatric       | 1.72%  | 10.59%    | 10.84%    | 12.32%    | 4.68%           | 55.17%          | 0.49%           | 4.19%  |         |
| Hospitalization   |        |           |           |           |                 |                 |                 |        | 0.0016% |
| Hospitalization – | 1.02%  | 4.08%     | 4.93%     | 5.27%     | 1.70%           | 1.53%           | 79.25%          | 2.21%  |         |
| somatic           |        |           |           |           |                 |                 |                 |        | 0.0016% |
| Prison            | 1.53%  | 11.09%    | 9.56%     | 7.27%     | 4.02%           | 3.06%           | 1.34%           | 62.14% | 0.0016% |
| Death             | 0.00%  | 0.00%     | 0.00%     | 0.00%     | 0.00%           | 0.00%           | 0.00%           | 0.00%  | 100%    |

|                   | Street | Temporary | Permanent | Emergency | Substance Abuse | Psychiatric     | Physical        | Prison | HF apt. | Death   |
|-------------------|--------|-----------|-----------|-----------|-----------------|-----------------|-----------------|--------|---------|---------|
|                   |        |           |           |           | treatment       | Hospitalization | Hospitalization |        |         |         |
| Street            | 95.79% | 1.28%     | 0.00%     | 1.28%     | 0.00%           | 0.26%           | 0.13%           | 0.26%  | 1.02%   | 0.0019% |
| Temporary         | 0.26%  | 90.22%    | 1.37%     | 1.79%     | 0.46%           | 0.75%           | 0.46%           | 0.59%  | 4.11%   | 0.0019% |
| Permanent         | 0.19%  | 3.13%     | 84.90%    | 2.26%     | 0.94%           | 0.56%           | 0.25%           | 0.44%  | 7.33%   | 0.0019% |
| Emergency         | 0.55%  | 3.43%     | 1.85%     | 82.50%    | 0.89%           | 1.44%           | 0.55%           | 0.96%  | 7.82%   | 0.0019% |
| Substance Abuse   | 0.00%  | 4.66%     | 2.21%     | 4.66%     | 70.59%          | 1.72%           | 0.49%           | 2.70%  | 12.99%  |         |
| treatment         |        |           |           |           |                 |                 |                 |        |         | 0.0019% |
| Psychiatric       | 0.20%  | 1.49%     | 2.19%     | 1.79%     | 1.19%           | 85.49%          | 0.50%           | 0.99%  | 6.16%   |         |
| Hospitalization   |        |           |           |           |                 |                 |                 |        |         | 0.0019% |
| Hospitalization – | 0.00%  | 5.48%     | 4.11%     | 3.42%     | 5.48%           | 2.05%           | 58.90%          | 2.74%  | 17.81%  |         |
| somatic           |        |           |           |           |                 |                 |                 |        |         | 0.0019% |
| Prison            | 0.18%  | 1.75%     | 1.29%     | 1.29%     | 1.01%           | 0.83%           | 0.18%           | 89.51% | 3.96%   | 0.0019% |
| HF apartment      | 0.04%  | 1.31%     | 1.21%     | 1.05%     | 0.49%           | 0.71%           | 0.25%           | 0.49%  | 94.45%  | 0.0019% |
| Death             | 0.00%  | 0.00%     | 0.00%     | 0.00%     | 0.00%           | 0.00%           | 0.00%           | 0.00%  | 0.00%   | 100%    |

Supplementary Table 4G: Transition matrix for HN, Homeless ≥ 2 years, HF

## Supplementary Table 4H: Transition matrix for: HN, Homeless ≥ 2 years, TAU

|                   | Street | Temporary | Permanent | Emergency | Substance Abuse | Psychiatric     | Physical        | Prison | Death   |
|-------------------|--------|-----------|-----------|-----------|-----------------|-----------------|-----------------|--------|---------|
|                   |        |           |           |           | treatment       | Hospitalization | Hospitalization |        |         |
| Street            | 96.51% | 0.74%     | 0.34%     | 1.34%     | 0.03%           | 0.54%           | 0.20%           | 0.30%  | 0.0019% |
| Temporary         | 0.30%  | 94.59%    | 1.55%     | 1.60%     | 0.37%           | 0.59%           | 0.37%           | 0.62%  | 0.0019% |
| Permanent         | 0.14%  | 2.10%     | 93.33%    | 2.02%     | 0.67%           | 0.89%           | 0.16%           | 0.69%  | 0.0019% |
| Emergency         | 0.57%  | 1.40%     | 1.32%     | 95.10%    | 0.35%           | 0.46%           | 0.25%           | 0.55%  | 0.0019% |
| Substance Abuse   | 0.51%  | 8.63%     | 6.35%     | 8.12%     | 71.07%          | 3.30%           | 1.02%           | 1.02%  |         |
| treatment         |        |           |           |           |                 |                 |                 |        | 0.0019% |
| Psychiatric       | 0.34%  | 1.39%     | 1.66%     | 1.63%     | 0.17%           | 94.03%          | 0.34%           | 0.44%  |         |
| Hospitalization   |        |           |           |           |                 |                 |                 |        | 0.0019% |
| Hospitalization – | 0.87%  | 3.64%     | 2.43%     | 2.95%     | 1.39%           | 1.04%           | 86.48%          | 1.21%  |         |
| somatic           |        |           |           |           |                 |                 |                 |        | 0.0019% |
| Prison            | 0.33%  | 1.27%     | 1.07%     | 1.10%     | 0.43%           | 0.57%           | 0.13%           | 95.10% | 0.0019% |
| Death             | 0.00%  | 0.00%     | 0.00%     | 0.00%     | 0.00%           | 0.00%           | 0.00%           | 0.00%  | 100%    |

#### 4.3 Supplementary Methods

#### 4.3.1 Death Rate

A death state was added to this model as over ten years it is likely that some individuals will succumb to death. As the Montreal AH/CS dataset lacked sufficient information to calculate the probability of transitioning to a death state, two outside data sources were used.

The Toronto portion of the AH/CS study followed individuals for a total of six years. Researchers at this site collected additional information on participants' death allowing us to calculate the average mortality rate over six years.<sup>15</sup> To reduce potential bias, deaths were aggregated across treatment groups and need levels.

Following Culhane et al., homeless individuals are estimated to have the health vulnerabilities of people up to 15 years older than their chronological age would indicate.<sup>111</sup> Therefore, the mortality rate was scaled to reflect the health of individuals experiencing homelessness and increased annually at the same rate as the rate of increase of the Canadian general population mortality rate for people 15 years older.

A linear equation was created to calculate the daily mortality rate using the Toronto mortality rate and the Canadian general age-stratified mortality rate. The Canadian general age-stratified mortality rate provided the annual increase while the intercept was determined by ensuring the average mortality rate over the first six years was equivalent to the average Toronto mortality

rate. Cohorts MN homeless < 2 years and MN homeless  $\ge 2$  years, have the same baseline age resulting in the same mortality rate equation. The result was three mortality rate equations:



Figure 5: Annual Daily Mortality Rate (Base Case)

MN, homeless < 2 years & MN, homeless  $\ge 2$  years: y = 0.0000027x + 0.0000136HN, homeless  $\ge 2$  years: y = 0.0000018x + 0.0000170HN, homeless < 2 years: y = 0.0000012x + 0.0000191

The daily mortality rate was converted to a daily probability of death using the following formula<sup>99</sup>:

Daily probability of death =  $1 - e^{-(daily mortality rate)}$ 

#### 4.3.2 Regression

Health, social and justice services (excluding costs associated with providing the intervention), and social assistance net of earned income was estimated using a generalized linear multivariable (GLM) regression model. To determine the most appropriate model, additive interactions were tested at a 0.05 significance level and multiplicative interactions were tested at a 0.1 significance level. The results were needs level being a significant additive interaction while needs level interacted with a night spent in the street as the only significant multiplicative interaction.

Once interaction terms were determined the Akaike Information Criterion (AIC) was used to determine the most appropriate combination distribution and link. Gaussian and Gamma distributions were tested in combination with identity and log links. A combination of a Gaussian distribution with an identity link was chosen for the multivariable regression.

#### 4.3.3 HF costs

The costs associated with providing ACT and ICM services and HF apartments were calculated separately. ACT and ICM costs included all costs associated with providing services (e.g. employee wages and program expenses such as travel, rent, and utilities). HF apartment costs included the cost of providing housing supplement and teams of housing specialists. Intervention expenses were distributed to each client based on their number and length of contacts with teams. All missing costs were imputed using Stata 16. Using weighted averages for each cohort, unit costs were calculated separately for HF apartments and for ACT and ICM.

The autonomization rate was applied only to costs associated with providing ACT and ICM services. Costs associated with providing HF apartments were not included in this rate.

#### 5. Discussion

This thesis comprising the manuscript examines the long-term cost-effectiveness of HF compared to TAU. The aim of the study was to (1) determine the costs and days of stable housing associated with HF and TAU and (2) to examine the effects of baseline differences on costs, housing stability, and cost-effectiveness. To answer these questions a cohort Markov model was created using the two-year dataset from the At Home/Chez Soi study in Montreal. Recognizing policymakers and public health officials aim to improve the health and well-being of the entire population, the analysis was carried out from a societal perspective, modified to include disability benefits and social assistance. Further, a DICE platform was chosen as it allows policymakers and researchers from different backgrounds to readily understand how the model functions.<sup>21,112</sup>

The primary result indicated that over a ten-year period HF was cost-saving compared to TAU. HF also averaged an additional 1,501 days of stable housing per person compared with TAU, while costing \$26,572 less. Thus, averaging across the entire cohort, HF dominated TAU.

Baseline demographics had a significant effect on cost-effectiveness. In all instances HF was more effective at achieving stable housing compared to TAU. However, two comparisons indicated HF was cost-saving (HN & homeless greater than or equal to two years, MN & homeless less than two years) while the other two indicated that HF was more effective at a higher cost (HN & homeless less than two years, MN & homeless greater than or equal to two years). Treatment group assignment was not significantly associated with outpatient health, social, justice, and vocational costs net of earned income. Consequently, differences in costs between the treatment groups stem from residential costs.

Individuals who were HN and homeless greater than or equal to two years had high baseline costs leading to interventions having a greater possibility for cost-offsets. In this model, HF appeared cost-saving for individuals who were HN and homeless greater than or equal to two years compared to TAU participants who spent proportionally more time in high-cost forms of housing. The result was HF substituting for high costs services, such as psychiatric hospitalization and emergency housing, thus leading to greater cost offsets.

Among individuals who were MN and homeless less than two years cost-savings stemmed from the TAU group spending proportionally more time in temporary housing. Compared to other forms of housing, TAU, MN, and homeless less than two years participants had high probabilities of transitioning into and staying in temporary housing. Additionally, this group had the highest residential cost for temporary housing (\$61.20 versus \$33.08 in the comparison HF group). The high cost of temporary housing for this group is a result of individuals tending to use high-cost forms of temporary housing (i.e. single room occupancy with support, transitional housing, or halfway housing). The total daily cost of temporary housing for an individual randomized to TAU and in the MN and homeless less than two years cohort is \$124.71 while the daily cost associated with staying in an HF apartment (where the greatest proportion of individuals stayed in the HF MN and homeless less than two years cohort) for individuals randomized to HF and in the same cohort is \$75.27. Thus, cost-savings in this group stem from HF substituting for relatively high cost forms of temporary housing. It is not entirely clear why

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we observe this pattern in the data, but it is possible that individuals with more moderate needs who have more recently become homeless may more easily appear as attractive candidates for selection committees of transitional housing settings.

Even among cohorts where there was a net additional cost, the cost was comparable to the costs of existing, currently funded, supportive housing programs. Among those who were HN and homeless less than two years and those who were MN and homeless longer than two years, the cost per additional day of stable housing was \$36.40 and \$16.82 respectively. Thus, regardless of cohort, providing HF is either cheaper than TAU, or else costs vary little in comparison with currently-funded types of services.

Should the decision-maker choose to only provide HF to cost-saving cohorts, those currently MN and homeless greater than or equal to two years, and those HN and homeless less than two years would need to either stay homeless for longer or increase their need level. This would result in these two cohorts of individuals meeting the criteria for the HN and homeless greater than or equal to two years cohort (i.e. the most cost-saving cohort). The decisionmaker would thereby be conveying the notion that individuals should experience homelessness for a minimum of two years or have increased mental illness and substance use before providing these individuals with HF. Additionally, as longer periods of homelessness have been tied to more severe mental illness and substance use, when these individuals achieve qualification for cost-saving HF, the cost of providing HF services will be greater.

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The majority of inputs used in this model were derived based on the number of days spent in a location (e.g. transition probabilities and residential costs). Therefore, it was deemed appropriate to only use data provided by individuals who had minimal loss of follow-up. Of the original 462 individuals included in the Montreal dataset, 36 (7.8%) were excluded due to more than 120 consecutive days of missing data. As these 36 individuals account for a small percentage of the total dataset, the resulting potential bias derived from excluding them in the analysis is also small. Multiple imputations could then be used to more accurately predict where the remaining individuals may have stayed on days with missing data.

As this model calculated HF cost using a weighted average from both imputed costs and imputed days, the costs associated with providing the HF intervention are slightly higher in this model than reported in other analyses. Compared with two-year cost-effectiveness studies, results from this model indicate that HF leads to more cost savings. At two years, HF for MN clients resulted in an additional \$56.08 per additional day of stable housing while HF for HN clients cost \$41.73 per additional day of stable housing.<sup>19,20</sup> Unlike previous AH/CS analyses, any place that imposed a maximum length was classified as temporary rather than stable housing. This more restrictive definition of stable housing is more consistent with Quebec and Canadian point-intime counts.<sup>23,24</sup> As a result, the difference in effectiveness compared to previous AH/CS studies is somewhat increased.

It is important to highlight that overall cost-effectiveness is dependent on the relative proportion of the number of individuals in each cohort. From a policy perspective, it is therefore beneficial, to interpret cost-effectiveness results of each cohort individually. In doing so, policy decisions can be made for jurisdictions with different proportions of citizens in each cohort.

In all instances, HF cohorts spent more time in permanent housing (either HF apartment or permanent housing). Conversely, TAU cohorts spent more time in temporary and emergency housing compared to the HF counterparts. The estimated transition probabilities drive these results. Individuals in HF cohorts exhibited high probabilities of transitioning into HF apartments from all types of housing. TAU cohorts tended to have lower transition probabilities out of states (meaning most individuals tended to stay where they presently were). Thus, in the first year, when the greatest change in the proportion of individuals in each state occurs, HF cohorts tend to transition quickly into HF apartments while less dramatic changes are observed in TAU cohorts.

Additionally, this model assumed that over ten years there would be no change in the cost of providing HF housing supplements. It is possible that an individual, after receiving HF supports, would re-integrate with society and in time sever ties from all HF supports. Therefore, we may have overestimated the costs of HF for the ten-year period.

HF clients report an improvement in quality of life scores and community functioning, perhaps implying that given a longer follow-up period clients would wish to return to work.<sup>13,59,90</sup> Integrating Individual Placement and Support, an evidence-based supportive employment intervention, into HF interventions may aid to achieve this goal.<sup>74</sup> Working aids in recovery, empowerment, and social integration, as well as contributes positively to society, suggesting the potential for further cost offsets.<sup>113</sup> As transition probabilities used in this model did not

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incorporate the potential effects of working on recovery and costs, long-term cost offsets may be under stated.

The autonomization rate of 2.5% may be conservative by at least one previous estimate. In an AH/CS extension study performed in Toronto, the autonomization rate was estimated to be 40% over 6 years, implying an annual rate of 7%. <sup>15</sup>

Sensitivity analyses investigated the effect of various levels in the autonomization of ICM or ACT services. In all cases, the aggregated cost-effectiveness indicated HF dominated TAU. Thus, even in the most extreme case where individuals were offered the same level of care by the ICM or ACT teams over ten years, HF was still cost-saving. With additional reductions in the care provided by ICM or ACT teams, HF resulted in increasing savings compared to TAU. If we take the 7% rate implied by the Toronto study at face value (it did not take into account individuals lost to follow-up), even the largest autonomization rate of 5% for the final 8 years used here is conservative. To the extent that this is the case, even our most optimistic scenario, with regards to the autonomization rate, may still underestimate cost-effectiveness.

Changing the discount rate had little effect on the results. This was to be expected as costs and benefits occur in line with each other.

Finally, a sensitivity analysis was performed on the linear death rate equation. A 95% confidence interval was determined for the death rate calculated from the Toronto extension study. The lower level of this 95% confidence interval was coupled with only a ten-year increase in each

cohorts' baseline age (the lower level for reflecting health vulnerabilities equivalent to that of individuals in the general population) used to determine the death rate of increase from the general Canadian population. The upper level of the 95% confidence interval was coupled with a 20-year increase for each cohort's baseline age. Changes in the death rate formula did not alter the model.

Results from this model can aid policymakers in making decisions regarding scarce resources. As long as there are individuals experiencing housing instability, then some will fall into homelessness. Thus, one cannot eliminate all emergency housing options, but converting a portion of existing housing services to HF programs is merited from an economic standpoint. This would allow individuals experiencing chronic homelessness the opportunity to re-integrate into society and contribute to personal and societal benefit. Additionally, greater cost savings can occur by reducing the period individuals experience housing instability.

#### 6. Strengths and Limitations

The model is grounded in data from a large cohort which provides strong empirical evidence allowing for investigation into the effect of baseline demographics. Nevertheless, the lack of data available to determine the probability of transitioning into a death state resulted in pooling data from multiple sources. While these are not a perfect proxy for what may occur in Montreal, data from Toronto and Canada as a whole offer similar services and climates for individuals experiencing homelessness. Additionally, sensitivity analyses on the mortality rate showed results were robust to fairly significant changes in the death rate. As with all models, the results are limited to the accuracy with which the model inputs were measured. It is possible through the creation of cohorts and grouping housing states, that some underlying trends were missed. In addition, transition probabilities estimated from two years of data may not reflect longer-term trends, such as individuals transitioning from transitional housing settings to other settings including permanent housing. The project did not recruit individuals who had been in transitional housing for a year or more and thus transition out of such housing could not be observed. Additionally, this model was constructed using a closed population (meaning no new individuals could enter) which is known to be an inaccurate representation of reality. Nonetheless, the model should provide a more realistic estimate of the long-term cost-effectiveness of HF compared to TAU than data from the first two years alone, given how atypical of long-term experience the first year is for the HF group in particular.

While a probabilistic sensitivity analysis would have provided a more comprehensive test of the robustness of results, the deterministic sensitivity analysis indicated results were quite robust to changes in several key parameters.

As with most economic evaluations, this model represents a simplification of reality. The Markovian assumption was employed in this model, and while it is highly unlikely that past events have no effect on future ones, we have minimized the inevitable uncertainty from trying to predict these future effects. We have investigated various levels of overall cost and effect discounting. We have also investigated the effect of long-term HF through a sensitivity analysis on the autonomization rate of ICM and ACT services. We calculated the cost of ICM and ACT services using weighted averages over the first two years. As individuals tended to spend more

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days in HF apartments in the second year this may have resulted in an overestimation of ICM and ACT costs associated with a day in an HF apartment from year 2 onwards. However, even at a 0% rate of autonomization results were robust.

We acknowledge that the true long-term effects of HF are unknown and the model required an important assumption that short-term effects would be maintained. Finally, this model used data from Montreal, and costs and outcomes may differ in other jurisdictions where resource use, costs, and available services may differ.

#### 7. Conclusion

This thesis illustrated that HF has the potential to be cost-saving in the long-term. Results also showed clients' need level and homelessness history have a significant effect on costeffectiveness. However, even among cohorts where cost-effectiveness was lowest, the cost per additional night of stable housing remained lower than the cost of a night in a shelter. Among all cohorts, HF led to greater housing stability.

The results contribute new information towards understanding the potential for long-term costeffectiveness of HF. Future research should be geared towards investigating cost-effectiveness across different jurisdictions and conducting long-term trials. Ultimately, such information on the long-term cost-effectiveness of HF will aid policymakers in making informed decisions about the best interventions to end homelessness.

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