Accessibility Improvement of China's Multi-Tier Health Care Network

A Discrete & Agent Simulation Study

Thesis Proposal Submitted to

Tsinghua University

by

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1. Topic Selection and Significance

The selected topic is the improvement of the multi-tier health care network in China. It aims to study the effects which the allocation of resources and designed guidelines in a country's multi-tier health care network have on the *accessibility* and *cost* of health services amongst different classes of respective citizens. The study will observe the health care network of China and the health service options for those in urban / rural areas.

This research will be significant because it could help deliver the right care to the right person in a much more effective manner. Also, it could aim to decrease the number of patients who need medical attention but cannot / choose not to receive it. The most important reasons for not receiving care is cost and accessibility. Therefore, the effects which health care costs and the options from which people have to pay will be studied in relation to many other factors in the populations' environment. The ways in which costs and accessibility in the health care are studied can be improved through a simulation study.

The goal is to intricately model an entire multi-tier healthcare network using *anylogic* agent/discrete based simulation software. This method will place agents (patients) who have specified characteristics within a modeled environment (healthcare network) and simulate the interactions of the two. Rules will be placed within the simulation to mimic the dozens if not hundreds of influencing factors of a patient's path to being healed in China. Valuable insight can be gained when measuring the effects of accessibility and cost across the system per different types of patients. By fine tuning the model, it is possible that any nation's health care network inform can be plugged in and adjusted; Thus, providing new customized recommendations.

2. Background Introduction

Firstly, let's clarify the definition of a multi-tier health care network. A *tier* refers to a health care level with different sources of funding, usually either *public* or *private*. Then within these tiers are many different nodes, or choices for health care facilities. When a patient needs medical attention, the path they take from node to node within their health care cycle is of much importance.

A *single-tier* network refers to a country that offers government funded universal health insurance to all its citizens. The key term for a single-tier system is *universal*. Popular examples of countries with universal health care include Canada, Australia, the U.K., Spain, etc. According to (Amadeo, 2019), the term universal means "a system that provides quality medical services to *all* citizens. The federal government offers it to everyone regardless of their ability to pay". Though the goal of a single-tier network is of pure intention, a potential problem in this definition is the word "quality". One of the issues with universal health care is that not all treatments are considered necessary, and the exact definition of quality can be manipulated such that some care is not provided the way the patient needs or prefers. Case examples of this will be provided in the literature review. This leads to the next level, two-tier networks.

A *two-tier* network is a health care system which incorporates both public and private funding. This can occur in two ways. The first combination includes 1) government funded insurance for *some* citizens who fall into certain categories (poverty, elderly, disabled, etc.) and 2) private insurance options purchased by individuals or corporations. The United States follows this scheme with government programs like *Obamacare* (based on income) and private insurance plans provided by employers or individually purchased.

The second two-tier combination is to have 1) universal health care provided to all citizens (such as the case with single-tier networks) with the extra option 2) to purchase additional private insurance plans for better quality and access. An example of this setup is the United Kingdom, previously listed as a single tier network. A source at (Internations.org, 2019) says the "UK offers affordable public health care to all residents via the NHS and HSC, there is often no pressing reason for people to buy private health insurance for themselves and their families. In fact, only 10.5% of the population, just under four million people, opted for private medical insurance." But still, a percentage of the UK population is seeking private insurance, thus technically classifying the UK as a two-tier network as opposed to a single-tier.

This technical occurrence is why many health care systems are considered *multi-tier*. It is very rare to find a true single-tier system in which the only insurance option is government

funded universal health care. All systems have some combination of both public and private payment across many different sub-levels (state, city, county, etc.).

Therefore, the terminology used in this thesis will be that of multi-tier networks. The general study objective is to perform an in-depth examination of China and the United States' multi-tier health care networks. To explore the different health care options and paths to being treated amongst different classes of citizens from the respective countries. For example, poor Americans in rural areas have which options provided to them? Then answer that same question for the respective Chinese class. Repeat these comparisons for the different classes within each country (lower, middle, upper) in rural / urban areas to define accessibility. Then, throughout the health care cycle, study the payment options available to define cost.

This process of a path will be defined as a *health care cycle*. It is the beginning to end path a patient takes from needing medical attention to having received care. It includes the *steps* and *nodes*. A step is a process in the healthcare cycle such as diagnosis, treatment, etc., and a node is the location where that step occurs. Note that in this definition, a patient is not necessarily healed or resolved of their issue, but they receive adequate care so that their problem is addressed and sent home. Whether or not they will need medical attention again for the same problem in the future is not of concern in this definition. However, it could lead to another unnecessary health care cycle in the future which is then of importance. As mentioned above, there are many nodes, or options, a patient can visit throughout their path. Examples of nodes include primary care, hospitals, specialists, etc. All of which can be either public or private. The number of steps and nodes in any health care cycle can be unlimited (n^{th} *degree*) depending on the patient's issue and preference. Also, there can be other types of steps and nodes not currently specified. Two examples of a path taken during a health care cycle are demonstrated in Figure 1:

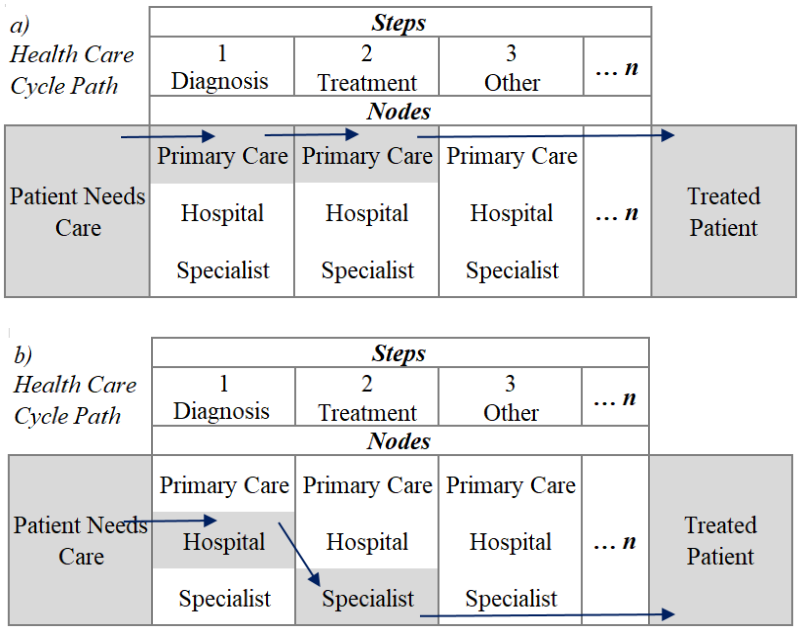


Figure 1: Example Pathways in Health Care Cycle

Figure 1 shows that a health care cycle begins at diagnosis and leads to treatment. Other following steps could be imaging, blood tests, check-up, or any other procedure which is not offered at that facility, or chosen to be performed elsewhere. This is often the case for insurance plans which only cover certain doctors or locations. Lastly, a health care cycle can have infinite n^{th} nodes / steps.

For example, Figure 1.a shows a patient who chooses to go to a primary care for diagnosis. Assume they have a cough and want to get it looked at. The primary physician decides he can handle and treat this patient and does so after diagnosing the cause of the cough. The patient is now finished and satisfied and can be concluded as treated. The total number of nodes in this healthcare cycle is one, since all steps were handled by the one primary care office. The total number of steps in this healthcare cycle is two: diagnosis and treatment.

In Figure 1.b, another patient chooses to first go to a hospital for diagnosis. The doctors at the hospital conclude that the cause of the cough is quite serious, and needs to go to a specialist for treatment. The patient is then treated at the specialist and concluded as treated. The total number of nodes in this health care cycle is two: hospital and specialist; while the total number of steps is also two: diagnosis and treatment.

In both healthcare cycles above, the patients are concluded as treated; however, the total costs and time can vary greatly depending on the steps taken and the total number of nodes. For example, specialists are generally more expensive than primary care. Also, the time to transition and schedule an appointment at a new second node can increase the length of time for the health care cycle.

Also, it is possible that the primary care missed something in the diagnosis that the hospital did not. So in the end, the patient in Figure 1.a may have paid less and gone home quicker, but they may suffer worse consequences in the future for inadequate diagnosis and treatment. Therefore, the goal is to minimize the time and cost of the treatments while maintaining quality across all stakeholders of the healthcare cycle.

Another consideration is that of efficiency for the whole health care network. If all patients choose to first go to a hospital for diagnosis, then capacity will quickly be used up and resources strained. Or if a patient goes to primary care to save costs and time during an emergency, they could suffer. Therefore, the questions of who, what, when, and where come to the surface for each healthcare cycle.

These problems are exactly what this thesis plans to study. All the questions and scenarios mentioned above can have many different variations and outcomes. In addition, the cultural, organizational, and managerial differences between China and the United States' multi-tier health care networks can make these complex health care cycles from patient to patient more interesting. That is why an industrial engineering approach is needed to analyze these networks. Modeling the networks as systems with different parts and input data can help simulate scenarios and provide recommendations. Next, a more specific research plan and methodology will be listed

Key words: Multi-tier health care network, health care cycle, path, steps, nodes, universal, agent / discrete simulation.

3. Literature Review (China)

Gathered from both domestic and international sources.

3.1. How to Measure Accessibility

This study cares mostly about measuring accessibility for the different types of patients. A difficult question to answer is how to measure these accessibility. The first step is to collect hard data on various metrics deemed important. According to (Services & Millman M, 1993), the following are major input factors which contribute to healthcare access:

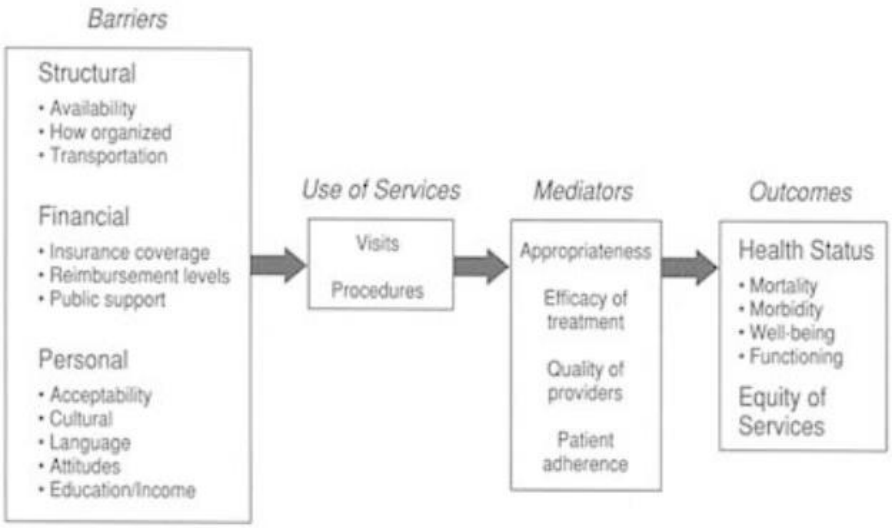
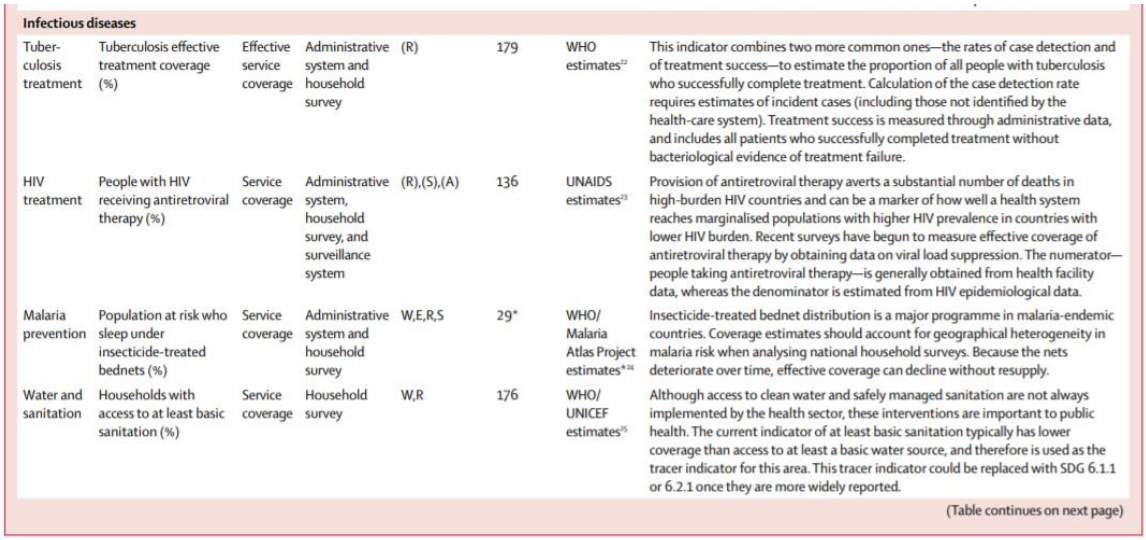


Figure 2: Accessibility Inputs

As far as measuring the output of healthcare access today, there are two basic metrics to measure health care access per nation. (Svetlana Doubova, 2018). Typically, access is measured through other metrics. The idea is that high access = lower health care problems.

1) **Service Coverage Index**: Considers data since 2010 for a result in 2015. Measures 16 health "tracers" including maternal / newborn, reproduction, infectious and non-communicable diseases, service capacity in relation to population, etc. The scale is 0 – 100, and a score of 80 is considered "passing". In 2015, respective scores were: **China: 76**; World: 63.738; USA: 80**.** (World Bank, 2019) (Daniel R Hogan, 2017)**.**

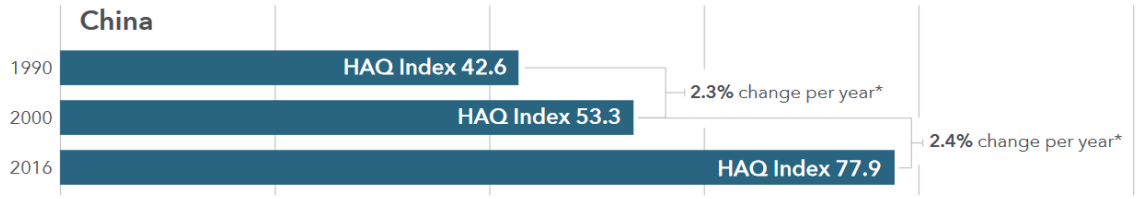


Infectious diseases							
Tuber-culosis treatment	Tuberculosis effective treatment coverage (%)	Effective service coverage	Administrative system and household survey	(R)	179	WHO estimates[22]	This indicator combines two more common ones—the rates of case detection and of treatment success—to estimate the proportion of all people with tuberculosis who successfully complete treatment. Calculation of the case detection rate requires estimates of incident cases (including those not identified by the health-care system). Treatment success is measured through administrative data, and includes all patients who successfully completed treatment without bacteriological evidence of treatment failure.
HIV treatment	People with HIV receiving antiretroviral therapy (%)	Service coverage	Administrative system, household survey, and surveillance system	(R),(S),(A)	136	UNAIDS estimates[23]	Provision of antiretroviral therapy averts a substantial number of deaths in high-burden HIV countries and can be a marker of how well a health system reaches marginalised populations with higher HIV prevalence in countries with lower HIV burden. Recent surveys have begun to measure effective coverage of antiretroviral therapy by obtaining data on viral load suppression. The numerator—people taking antiretroviral therapy—is generally obtained from health facility data, whereas the denominator is estimated from HIV epidemiological data.
Malaria prevention	Population at risk who sleep under insecticide-treated bednets (%)	Service coverage	Administrative system and household survey	W,E,R,S	29*	WHO/ Malaria Atlas Project estimates*[24]	Insecticide-treated bednet distribution is a major programme in malaria-endemic countries. Coverage estimates should account for geographical heterogeneity in malaria risk when analysing national household surveys. Because the nets deteriorate over time, effective coverage can decline without resupply.
Water and sanitation	Households with access to at least basic sanitation (%)	Service coverage	Household survey	W,R	176	WHO/ UNICEF estimates[25]	Although access to clean water and safely managed sanitation are not always implemented by the health sector, these interventions are important to public health. The current indicator of at least basic sanitation typically has lower coverage than access to at least a basic water source, and therefore is used as the tracer indicator for this area. This tracer indicator could be replaced with SDG 6.1.1 or 6.2.1 once they are more widely reported.

(Table continues on next page)

Figure 3: Examples of Service Coverage Index "Tracer"

2) The **Healthcare Access and Quality (HAQ) Index**: Also based out of 100, has been around for longer ,1990 – 2016, and it focuses on mortality rates of 32 diseases that should not be killing patients if there is quality access to basic medical care.



Use in Simulation: After applying the specified rules and data into the simulation, measure the results on the same metrics used in one of these indexes.

3.2. Current Health Care Network Simulations

Agent Based Simulation: Assigns behaviors and rules to agents. The agents are components of an entire system and can be people, companies, products, and more. Then they are placed in a specified environment with their interactions simulated.

Discrete-Event Simulation: Observes the processes of a system as a sequence of events occurring at a specific point in time. In this process, a change in events equals a change in the entire system, with the assumption that no change in the system occurs *between* events.

Since the planned thesis model will factor in multiple stakeholders (doctors, patients, diseases), it is important they be able to interact with each other. Since the number of doctors can influence the number of treated patients and thus the rate of diseases. Therefore, an agent-based model is required. To reflect the hierarchal nature and step-like procedure of a patient's path to being healed, it is important to also implement discrete-event simulation. Therefore, a combination of agent-based and discrete simulation will be used. This type of simulation is possible using anylogic software.

3.3. Nodes & Structures

China is composed of both public and private health care nodes (options). In 2011, private health facilities were at 48%. It is estimated that the number of private facilities grows at about 3% per year. In 2017, the private sector accounted for 60% of all facilities, more or less supporting this 3% growth rate. According to statistics from the National Health Commission, there were more than 18,000 private hospitals at the end of 2017 in China, exceeding that of public hospitals. But there were only 490 million visits, less than 15% of the total visits (Zheng Yiran, 2018). The following chart summarizes the healthcare hierarchy, structure and *nodes,* in China. (Meng, Yang, Chen, Sun, & Liu, 2015), (Yuelian Sun, 2017).

				Type					Target Patients
	Quality Control	Institution Level	Level	Medical Service Delivery		Health System	Medical Service & Health System		
Public	NHFCP: Quality Ranking: A, B, C	3) Tertiary	State	State TCM Hospital	State General Hospital	State CDC	Medical College	University Hospitals	To be studied
			Provincial	Provincial TCM Hospital	Provincial General Hospital	Provincial CDC, MCHI			
		2) Secondary	City	City TCM hospital	City General hospital	City CDC, MCHI			
			District	District TCM	District General Hospital	District CDC, MCHI			
		1) Primary	Town	Community Health Service Center	Community Health Service Station	Township Hospital	Village Clinic	-	
Private	Business License: State Administration for Industry and Commerce (SAIC)	Private	Private (local)	Private TCM Hospital	Private General Hospital	Private Health Care clinic	other	-	

Notes:

Tertiary	500 < beds, provide specialist health services, extensive health care, curative treatment, and great emphasis on medical education and research
Secondary	100 < beds < 500, comprehensive health services, curative treatment some medical education, and research
Primary	beds < 100, minimal equipment, focus on preventative medicine, rehabilitation, and general health care
Quality Ranking	All public institutions at each level ranked "A, B, or C" based on functions, size, technical skills, equipment, and quality of service. "A" in level 3 is the best
Private Health Care	Usually small and limited services. The 48% of all health care facilities employed 17% of all health staff and 9% of beds. Continuing to increase.

Next, we can compare the previous table to reports on China's Statistical yearbook for healthcare institutions. In the report, the heading titles for different health institutions is also separated into three categories. Seeing how the national government classifies and accounts for their healthcare options will clearly list the possible nodes in China's multi-tier network. This example reformats data from the report in a clearer manner for Beijing in 2017. (China, 2017)

Type	Sub Type	2017 Number
Hospitals	General	272
	TCM	154
	Specialists	169
Healthcare institutions (grass roots)	Community Health Service	1915
	Township Health Centers	0
	Village Clinics	2729
	Outpatient Department	4264
Specialized Public Health institutions	CDC	29
	Specialized Disease Prevention and Treatment Institution	25
	Women and Children Care Agency	20
	Health Inspection Center	18
	Total	**9595**

Here we see that in Beijing, a patient in need of care has 11 possible nodes to choose from, according to their need.

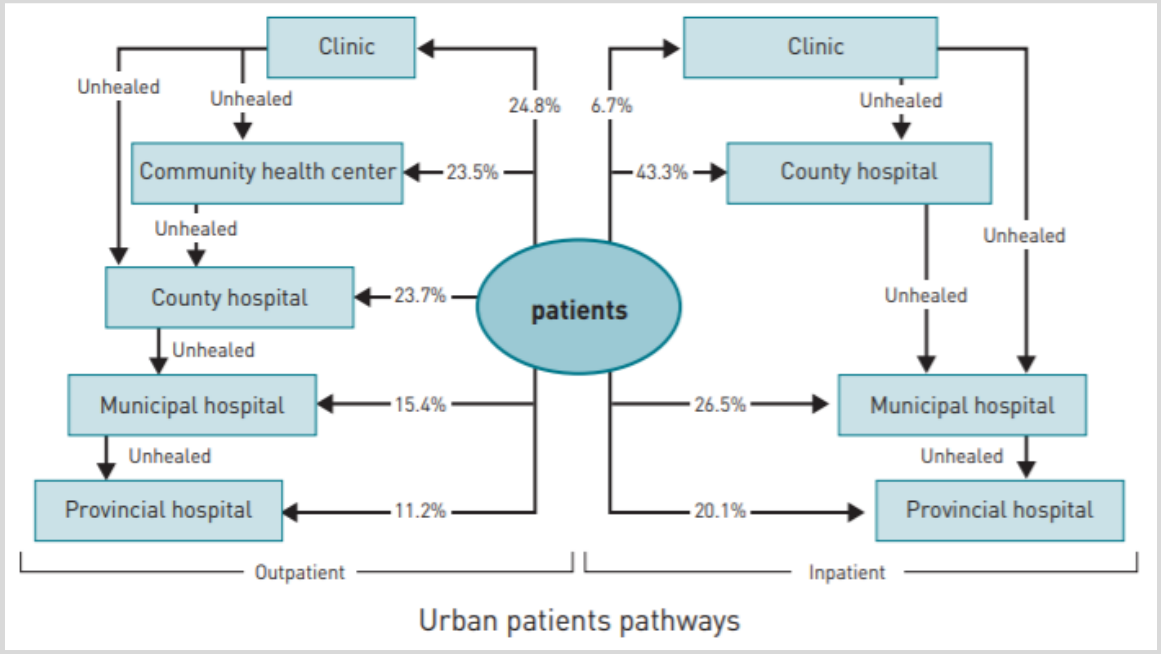
Next let's summarize how Chinese patients can move from node to node.

In 2006, The China National Development and Reform Commission (CNDRC) performed a survey to gauge Chinese patient's receptiveness to CHS's (Community Health Service), also known as primary care. The survey was a follow up to test the effectiveness of some legislation passed in the late 1990's. This legislation's aim was to 1) focus on community first treatment, which means to seek care on a lower level first, and 2) the two-way referral system, meaning doctors at any of the nodes can forward patients up and down the stream as needed. (Wenya Yu1, 2017). The survey results showed that 30% had no preference to a hospital or CHS. But of the remaining, around 41% would not go to a CHS if ill, while about 28% would be okay with a CHS as their first choice. Then to measure the two-way referral system, the CNDRC also analyzed the makeup of referral rates. They found a severe imbalance of upward vs. downward mobility. Ideally, there should be higher downward referral rates to lessen the strain on hospitals. Based on studies from the WHO, 70–80% of diseases can be diagnosed and treated in CHSs, thus reducing medical costs by 8–16%. However, of all China's health visits in 2006, only 11% of patients had a referral (The WHO recommends 20-30%). And of these 11%, a large proportion were upward referrals, about 9 percent. This all equals a high strain on hospitals, reflecting a general mistrust of primary care amongst Chinese patients.

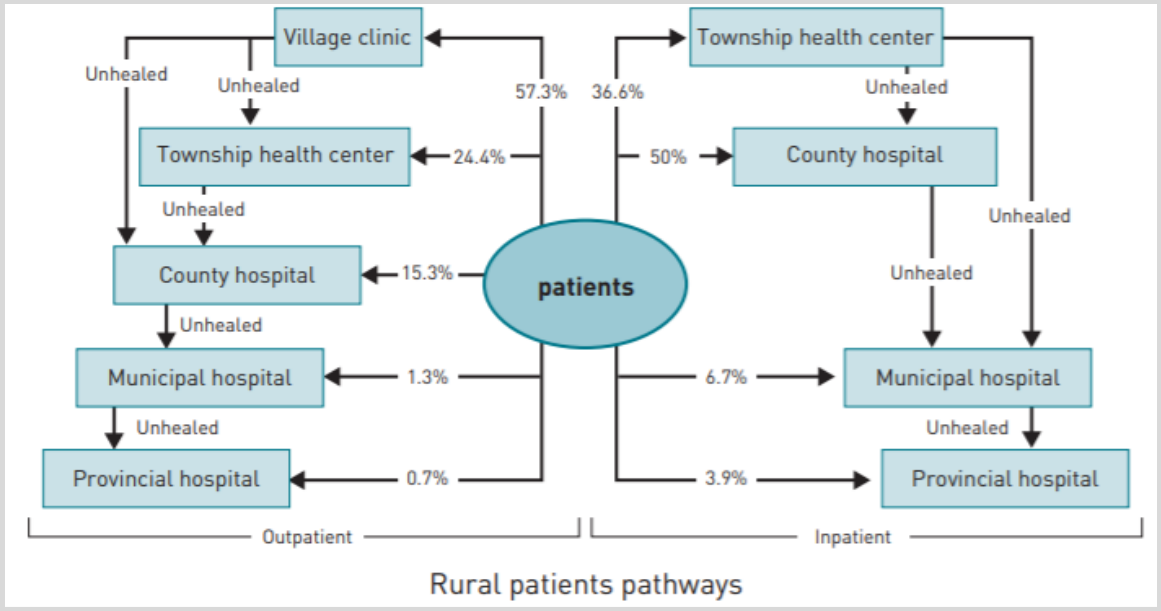
To this day, Public hospitals still play a dominant role in China while private hospitals are in a weak position due to lack of resources, poor medical insurance coverage for private, and weak branding (Zheng Yiran, 2018). (Wee, 2018). If China can spend more to update CHS facilities (staffing, beds, tech), then the perception of these nodes can increase. Currently, China's health care spending (5.4 percent of GDP) of 2013, is still lower compared to OECD countries This means China can start to invest more in the healthcare industry since their demand is increasing due to an aging population and continued urbanization. (Nofri, 2015).

Understanding the effects of referrals and CHS perception can provide great insight to measuring accessibility for the whole network. Therefore, these two will definitely be included in the simulation.

Next we have this example from (Meng, Yang, Chen, Sun, & Liu, 2015) which demonstrates the probability of urban / rural patients going to a specific type of node in China. This helps determine the common paths for each type of patient in different countries.



Urban patients pathways



Rural patients pathways

3.4. Payment Options

In China, over 95% of the population is covered by some form of *public* insurance since 2011. However, health services require patients to pay for services upfront and out of pocket. Depending on the insurance scheme and treatment, there may be reimbursement for some or none of the costs. (Internations.org, 2019)

Public insurance is divided into three categories: 1) urban employment-based basic medical insurance; 2) urban resident basic medical insurance; and 3) the new cooperative medical scheme for rural residents.

- The *urban employment-based basic medical insurance (UEBMI)* is obligatory and has comparatively little government spending. It is mainly funded by payroll taxes from the employee and employer: 6% of salary cost paid by the employer plus 2% by the employee make up its contribution (varies per local government). Different proportions of these revenues go to fund two accounts: the medical savings account (MSA) and social pooling account (SPA). The MSA handles outpatient and emergency services while SPA handles inpatient. Local governments set the level of deductibles, copayments, and reimbursement caps based on local economic level. Non-employed family members cannot be extended coverage. In 2014, this insured Population was around **283 million**. (Nofri, 2015), (Hai Fang, n.d.).

- The *urban resident basic medical insurance (URBMI)* works to cover the remaining unemployed urban residents (families, disabled, students). Its contributions consist of premiums and government subsidies. Premiums also vary based on local government, but it considers the individuals' medical care expense level and household income. This means higher subsidies for lower earning families.

- The *New Cooperative Medical Scheme for Rural Residents (NRCM):* This scheme was developed to balance the inequality in health care coverage for rural residents who do not enjoy the benefits of modern urban development. As of 2010, roughly 90% of rural residents were covered by this insurance plan. It is aimed at helping farmers, but is not exclusive to this group. Therefore, membership is voluntary and available to those who live in areas where the scheme is available.

	Urban Employee Basic Medical Insurance	Urban Resident Basic Medical Insurance	New Rural Cooperative Medical Insurance
Launching Time	1998	2007	2003
Insured Population	Urban Employee	Urban Resident who are not covered by UEBMI	Rural Resident
Risk Pools	County level	City level	City level
Premium Paid By	Employer and Employee	Government and insured individual	Government and insured individual
Annual Premium Level (2012)	Employer pays 6% of employee's wage, employee pays 2% of the wage	At least 300 CNY, in which government pays 240 CHY/ insured	At least 300 CNY, in which government pays 240 CHY/ insured
Reimbursement Cap (2012)	6 times of local average salary (at least 60000 CNY)	6 times of local per capita income (at least 60000 CNY)	8 times of local per capita income (at least 60000 CNY)
Covered Services			
Inpatient Services	Covered	Covered	Covered
Outpatient Services for Catastrophic Illnesses	Covered	Covered	Covered
General outpatient services	Covered	Limited and vary by location	Limited and vary by location
Number of Insured at 2010 Year-end (Million)	237	195	836

Figure 4: Summary of China's 3 public insurance plans

(Henu Zhao, 2019)

This table is a good example of some healthcare policy in China. We can see the rural citizens are offered a higher reimbursement cap based on their salary. Seeing how they may have more problems due to their environment and less salary from which to pay for.

Now let's look in more detail the breakdown of one of these insurance plans for inpatient and outpatient coverage: (UEBMI). Remember that this insurance plan is funded in part by the employer and employee, and goes to two different accounts, MSA vs. SPA, to pay for different services for those working insured. This information was gathered and translated from a local Beijing friend regarding her insurance coverage at her company.

Outpatient Coverage

Category	Insured		Deductible line	Reimbursement ratio	Supplementary medical insurance	Capping line	Appointed hospital
Outpatient Coverage	In-service	Community health service agencies within the city	1800	90.0%		20000	Four basic hospitals are selected from the designated hospitals. In addition, one can go directly to Class A hospitals, designated Chinese medicine hospitals and designated specialist hospitals.
		Non-community health service		70.0%			
	Retiree	Under 70 years old (Community health service agencies within the city)	1300	70.0%	15%	20000	
		Under 70 years old (Non-community health service)		80.0%	10.0%		
		70 years old or older		80.0%	10.0%		

Figure 5: EUBMI Outpatient Coverage Details

Inpatient Coverage

Category	Insured	Coordinated fund payment						Mutual medical fund for large-scale of payment		
		Deductible line					Capping line	Reimbursement ratio	Capping line	Note
Inpatient Coverage	In-service	1300		Tertiary hospital	Secondary hospital	Primary hospital	100000	85%	200000	For large-scale payment in a single hospitalization which exceeds 70000 needs to be reported to the medical insurance review.
			1300—30000	85%	87%	90.0%				
			30000—40000	90.0%	92%	95%				
			40000—100000	95%	97%	97%				
	Retiree	1300		Tertiary hospital	Secondary hospital	Primary hospital		90.0%		
			1300—30000	91%	92.2%	94%	100000			
			30000—40000	94%	95.2%	97%				
			40000—100000	97%	98.2%	98.2%				

Figure 6: UEBMI Inpatient Coverage Details

These two tables show another example of China's healthcare policy in action, with a specific goal in mind. For inpatient coverage, notice that a greater percentage of costs are covered at primary care institutions vs. tertiary. Meaning if patients go to primary care instead for treatment, they can get more money back. It can be deduced that the purpose of this is to encourage patients to seek care at lower, primary levels; thus, lessening the strain at tertiary hospitals. You can see the same phenomenon in the outpatient table for community vs. non-community health service agencies. Lastly, you can see the max reimbursement cap of 200,000 RMB. The policy for reimbursement cap is equal to 6* annual local salary. This equates the Beijing local salary to (200,000 / 6) / 12 = 2,777 per month, which I personally find to be an unrealistic representation of average Beijing salary.

For the public health insurance, there are some things which are not covered, such as emergency transportation, or the ability to switch to private hospitals. In fact, visitors of public hospitals can pay extra for VIP wards, with nicer rooms and more personal treatment Hospitals are allowed to have up to 10% of their space allocated to such wards. (Jonathan Zhao).

What will be interesting to study in the simulation is to model a paying capacity of patients into the population. Factoring in their average income and insurance coverage, how does this affect if and where a patient will go.

Commercial private health insurance became available in the 1980's (Meng, Yang, Chen, Sun, & Liu, 2015). Because of the relatively low reimbursement cap of insurance plans, the trend of private insurance has increased to further supplement such cases as catastrophic accidents. From 2008 – 2012, the number of private hospitals doubled from 5,400 – 9,800. (Jonathan Zhao).

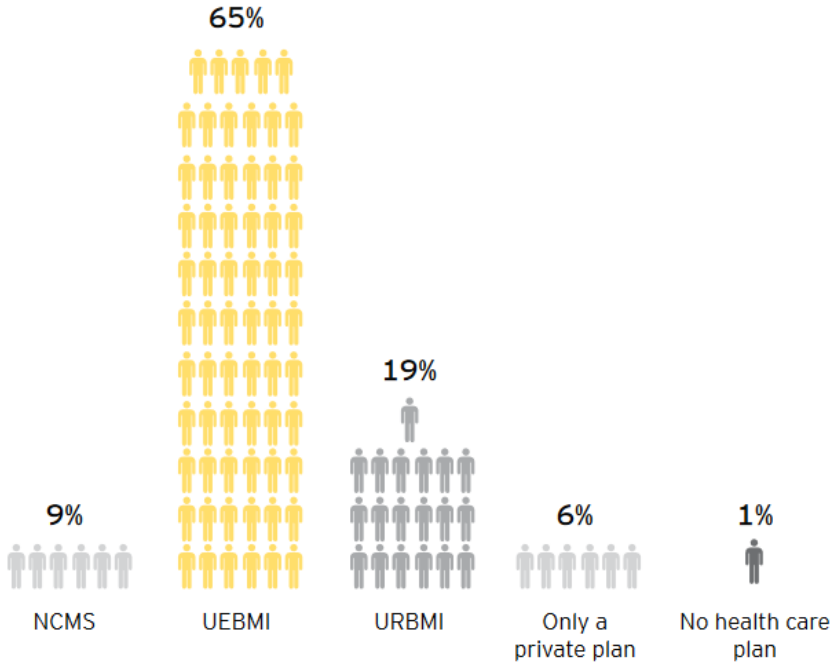


Figure 7: China Insurance Options Summary

3.5. Health Demographics Intro & Main Problems

This section aims to introduce the patients and countries of interest. One of the quickest ways to analyze a country's current health situation on a surface level is average life expectancy from birth. If people are living longer, then that is a good sign; though there

are deeper influences for one country's life expectancy. The following figure (World Bank, 2019) shows the life expectancies for China, U.S., and the world average from 1960 – 2017. This time period was chosen because it is long enough to incorporate recent historical and political events and also because it is as far back as the WHO data goes.

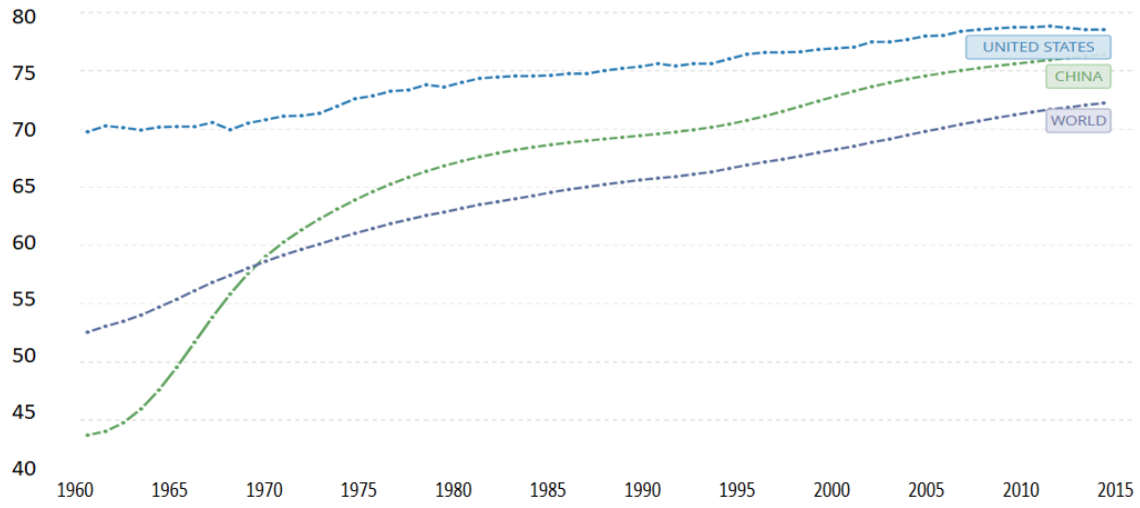


Figure 8: Life Expectancy Comparisons

Here we can see that current life expectancy (2017) for China and the U.S. differ by only two years: +- 77 years life expectancy. Both life expectancies are above the 2017 world average of 72 years. In 2017, China's population was 1.38 billion, while the U.S. was 325.7 million. Logically, it can be stated that it is much harder to maintain a higher life expectancy for a much larger population. More people equals more problems. This large gap in populations portrays a large improvement in China's health care system, while the U.S. has maintained a steady and slowly increasing improvement. Other important measures of health include birth, death, and non-communicable disease rates. During the same time period of the graph above, we can summarize these rates for both countries as well:

Year	Birth Rate (per 1,000)		Death Rate (per 1,000)		Non-Communicable Disease (% of all deaths)	
	China	U.S.	China	U.S.	China	U.S.
1960	20.86	23.7	25.43	9.5	-	-
2017	12.43	11.8	7.11	8.5	89.3%	88.3%

Figure 9: Birth, Death, & Non-Communicable rates in China / U.S.

These three statistics do not necessarily reflect the current state of health care in a nation, but rather reflect the need of healthcare services. They are important for several reasons:

- Together, birth and death rate show the speed at which a population is growing or declining (Population Reference Bureau, 2009). If we compare the two rates for both countries, we can see that China is growing at a faster rate than the U.S. as of 2017: [(12.43– 7.11) - (11.8 – 8.5)] = 2.02 per 1,000.
    - Since it is per 1,000 of the whole population, this 2.02 difference in increase is further amplified by China's already larger population: [(12.43– 7.11) * (1.386 billion / 1,000)] = 7.4 million total increase for the next year. Whereas the U.S. = [(11.8 – 8.5) * (325.7 million / 1,000)] = 1.1 million total increase for the next year.
    - This means that China will have a greater need to expand its healthcare network capabilities in order to serve the larger and increasing population.

- Since a large percentage of the death rate is constituted by non-communicable diseases, the ability to screen and treat these diseases reflects greatly on the abilities of the health network. Non-communicable diseases are important because they are not the typical and temporary cold or flu which are easily treated. Though a large proportion of non-communicable diseases can be genetic (uncontrollable), the remaining are usually a result of life style and environment. Decreasing the prevalence of non-communicable disease is a goal of the government, but it is a much more arduous task compared to increasing the health services offered to these individuals so they can live longer and better lives.

- In both China and the U.S., we can see a change "from a high birth rate, high death rate, and communicable disease to having a low birth rate, low death rate, and non-communicable chronic diseases". Meaning that the spread of infectious diseases are generally under control. Therefore, "rapid urbanization and industrialization, large-scale migration and population ageing, and lifestyle factors and environmental pollution have become the major health concerns" for both countries. (Meng, Yang, Chen, Sun, & Liu, 2015)

Next is morbidity rate and mortality rate. These metrics measure the prevalence of specific diseases in a population. Morbidity measures the frequency of occurrence, whereas morbidity measures the frequency of death (Husain, 2019). These two rates will vary from disease to disease. Examining which diseases rank high per nation can give some insight to the health care network. For example, a fairly manageable disease with a high mortality rate reflects poorly.

Since the 1990's, the top killers for both China and the U.S. have moved from infectious diseases to non-communicable diseases. Rapid urbanization can help foster the spread of infectious diseases, so it is important these two countries maintain and continue to grow health care networks which can prevent and treat the new top killers of non-communicable diseases. (ChinaDaily, 2019) (University of Pennsylvania, 2016)

Upcoming Problems

According to (Ke Xu, 2009), in order to lessen the discrepancy in health coverage for their rural citizens, China had two options. The first is to design an insurance plan that covers basic care for many rural citizens. The second option is to develop more comprehensive care for a smaller proportion of the rural population. China's New Cooperative Medical Scheme for Rural Residents (NRCM) fits more with option one. Therefore, there is an increased health demand in rural areas with an inadequate network. Therefore, continued investment from China's government is needed to build the infrastructure and stack that developed network with professional staff and up to date medical equipment / practices.

Though China's healthcare market is second largest in the world, the percentage of GDP spent on healthcare (about 6%) is still immature compared to other developed countries

such as the U.S. (about 17% of GDP on healthcare. (Dezan Shira, 2018). This means that China will need to continue investment for its larger population.

Healthcare Market Size 2009-2017

Year	Market size (Billion RMB)	Growth rate
2010	1,930.8	24%
2011	2,592.3	34%
2012	2,991.5	15%
2013	3,736.3	25%
2014	4,498.8	20%
2015	4,998.5	11%
2016	5,607.3	12%
2017E	6,216.1	11%

Source: Open source reports

Figure 10: Chinese Health Market Growth

In addition, China has an increasing aging population. In the case of the urban employment-based basic medical insurance (UEBMI), these retired patients are still covered by the insurance without contributing a 2% of annual salary towards the fund, thus demanding more from the system.

Lastly, Chinese doctors are paid comparatively lower wages, and their salary is usually tied to hospital performance. This leads to doctors increasing the sales performance of drugs to better hospital profits thus increasing their takeaway. This kind of tactic results in around 40% of hospital revenues relying on the sale of drugs. This is too dependent and passes too much cost on to the patient. (Jonathan Zhao).

4. Extra Literature Review & Survey

- Governing bodies and specific health laws
- Perform a stakeholder analysis of each healthcare network. Consider the patients, hospitals, doctors, and payers (insurance) and identify pros and cons per country. Also note any similarities / differences in the two.

- Online health care
- The survey will not be used in the in-depth network modeling. Its primary goal is to generally gauge the domestic and foreign local bodies on basic healthcare questions. Such as:
  - What is your preferred health care option for certain kinds of symptom?
  - At what monetary value do you think is too much to see a doctor?
  - How many times did you visit the doctor this year?
  - Compare previous question's answer to their insurance contributions.
  - Have you experience with online healthcare? What is your receptiveness to this?
  - Etc.

Previous healthcare surveys such as this example from (Wenya Yu1, 2017) base a patient's acceptance of downward referral (on education and professional backgrounds. Arguing that China's low rate in downward referrals is a problem stemming from lack of medical education. Inferring that Chinese patients usually equate quality medical care as coming from only 'the best' doctors employed by tertiary hospitals.

Table 1 Doctors' sociodemographic characteristics and practices and attitudes towards downward referral

Category	N (%)	Willingness of downward referral		χ^2‡	p Value§
		Yes (A*, T†)	No (A*, T†)		
Part I: sociodemographic characteristics					
Gender				0.077	0.781
Male	430 (55.6)	88 (89.6)	342 (340.4)		
Female	343 (44.4)	73 (71.4)	270 (271.6)		
Age				2.836	0.418
20–29	139 (18.0)	34 (29.0)	105 (110.1)		
30–39	404 (52.3)	85 (84.1)	319 (319.9)		
40–49	182 (23.5)	31 (37.9)	151 (144.1)		
50–59	48 (6.2)	11 (10.0)	37 (38.0)		
Level of education				14.905	0.002
Junior college degree	7 (0.9)	3 (1.5)	4 (5.5)		
Bachelor's degree	211 (27.3)	57 (43.9)	154 (167.1)		
Master's degree	352 (45.5)	75 (73.3)	277 (278.7)		
Doctor's degree	203 (26.3)	26 (42.3)	177 (160.7)		
Professional title				4.122	0.249
Junior and others	263 (34.0)	63 (54.8)	200 (208.2)		
Intermediate	326 (42.2)	68 (67.9)	258 (258.1)		
Associate senior	133 (17.2)	23 (27.7)	110 (105.3)		
Senior	51 (6.6)	7 (10.6)	44 (40.4)		

Figure 11: Survey Example

5. Research Plan & Methodology

Qualitative	Quantitative
Literature Review Answer the research and supporting questions using domestic and international sources for an up to date standing on both countries multi-tier health networks. Data mine.	*Simulate Accessibility* Use data from literature review to create a customized discrete & agent-based simulation in anylogic. The simulation will include data points such as nodes, path probability, income distribution, population densities, morbidity rates, etc. The measured output is accessibiltiy
Survey Survey local and foreign residents on topics related to literature review. Perform statistical analysis on results.	*Modeling Cost* Tweak inputs of simulatuion to optimize accessbility. Then create a cost model and factor in recommendations to see the effect on cost for payer.
Reccommendation to be determined	

Figure 12: Research Plan

Qualitative Research Question and Objective:

The research plan of this thesis can be divided into two main parts: Qualitative and Quantitative study. Combined, the two will the answer this very important question: How can the multi-tier healthcare networks in China and the U.S. be improved through the guideline and resource allocation changes. Improvement will mainly be measured by increased accessibility and decreased costs for the payer(s). The qualitative research will be based on literature review and surveys, while the quantitative research is based on modeling and simulations of the networks. The objective is to increase the efficiency and accessibility of health care networks by reducing strain of resources and maintaining quality. The effect on cost is still unknown.

Supporting research questions:

- What are the current health demographics and health demand of each population?
- What are the available nodes in China and the United States' multi-tier healthcare networks? Also, what is the general setup of each network, in terms of demand, funding, number of facilities, types of facilities, service offerings, and more?
- What are the common health care cycles for different illnesses in both countries? See Figure 1: Example Pathways in Health Care Cycle.
- What are the different public and private insurance plans, and how do these payment methods affect different classes of patients?
- How does accessibility and quality of care vary from class to class for each country? For example, is the discrepancy in health care between the poor and rich greater or lower in China or the U.S.?
- What are the current health standings of the two populations? Measure by health care metrics such as morbidity rate and more. Compare these statistics to the rating of health care networks and also the budgets allocated by the governments.
- What are the differences in stakeholder analyses for the two countries healthcare networks? By recognizing motivation and constraints, more insight in policy can be gained What are the cultural differences in perception of certain health care questions? Such as choice of facility, weight of importance for which doctor treats you, when to see a doctor, etc.
- What is the current standing and applications of online healthcare applications, such as apps that can diagnose patients from home? How could these lessen the burned on current healthcare networks?
- What are the general opinions of current health care networks amongst local citizens (survey), and how much information can be gathered on patients who have experienced both health care networks?
- What government policies (local / state / federal) have been implemented to enact change in health care?
- What are some special cases in history for both health care networks?
- And more…

Data Sources

Data sources planned for this study include but are not limited to: Tsinghua Web of Science, World Health Organization (WHO), the Organization for Economic Co-operation and Development (OECD) health data, the International Monetary Fund (IMF), International Common Wealth fund, the World Bank, respective national statistical offices such as the National Bureau of Statistics (China) and data.gov (USA), census reports, previously published research works, thesis survey / outside surveys, and more.

Quantitative Simulation & Modeling

By viewing the healthcare network as a system, a model can be made to minimize such variables as cost and time or maximize variables such as accessibility and efficiency. All of these can be measured in some way.

The process for the proposed simulation could be the following:

1) Research current models for measuring access and cost in healthcare networks.

2) Find all available nodes for a multi-tier healthcare network; by province (China) and state (U.S). Distinguish between public and private.

3) Find the demand for each type of node. This can be done by:
   - Analyzing historical demand data for hospitals, specialists, etc.
   - Working backwards: determine the service type / main services per node. Then predict the upcoming demand for those specific services based on related illnesses' growth rates.

4) Determine the probability of a certain type of person going to a certain type of node for a specific step.

5) Consider any government / policy constraints for moving within the network. For example, referrals to specialists only, booking appointments, etc.

6) Research other factors such as:
   - **Distances** to nearest relevant node
   - **Probability** of correct diagnosis
   - **Probability** of correct treatment
   - **Costs** of different steps in the healthcare cycle **per node**
   - **Wait times**
   - **Service times**
   - **Capacity** of each node type
   - **Service capabilities** of each node type
   - **Income distribution** of patients
   - **Morbidity rates** per population
   - **Other health and population demographics**
   - **Type** public vs. private
   - **Technology level, number of beds, staffing levels in each node type**
   - Etc.

7) Combine all these variables into an accessibility model to use in simulation.

8) Run simulation of periods of time and observe changes in accessibility. Tweak simulation until results are similar to actual, current accessibility.

9) Change inputs in simulation and see what increases accessibility.

10) Take these recommendations and next model the effects on cost. Pick the best outcomes: Examples include:

Changed Measure	Observed Effects
Minimize/maximize the sum of all nodes	**Accessibility**: *precise measurements of accessibility refer to section 4.1*
Change in service capabilities amongst nodes	
Stakeholder cost adjustments	
Policy Adjustment (referrals).	
Change in insurance coverage	
Increasing or decreasing the amount of certain types of nodes	

11) Factor in and experiment the online healthcare node to see the effects on the networks.

Simulation Confirmation

Use customized any logic simulation or other pre-establish simulation models on anylogic cloud to run the simulation again using any changed recommendations from the model.

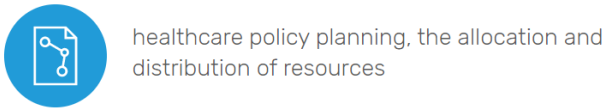


Figure 13: Anylogic Healthcare Simulation

Hypothesis

China: An increase in the number of lower level primary care facilities will not be enough to increase accessibility. The addition of policies to restrict / force patients to go to certain nodes for certain conditions will increase the efficiency, thus encouraging accessibility. Also, with the investment in more primary care facilities, the technology and service capabilities of these nodes should be upgraded to improve public perception.

Lastly, altering the values and percentages of deductible's, caps, and reimbursements will have a significant effect

6. Schedule of Thesis Writing and Proposed Date of Defense

Month	Task	
October	familiarize with anylogic	More indepth literature review
November		
December	model accessibility in anylogic	
January		Begin Survey
February	Analyze results, adjust model and note affects on cost.	Continue survey
March	tweak model and simulation as needed	Statistical analysis of survey
April	Combine all works into final thesis. Format and fluid check	
May	Submit	
June	Final Defense	
July	Graduate	

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