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Refugees in Urban Environments: Social, Economic, and Infrastructure Impacts

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REFUGEES IN URBAN ENVIRONMENTS:
SOCIAL, ECONOMIC, AND INFRASTRUCTURE IMPACTS

THESIS

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Abstract

The United Nations High Commissioner for Refugees has estimated that in 2015 there were 21.3 million refugees worldwide; it is estimated that 1.8 million of these persons were newly displaced during 2015. As refugees leave their country to seek the protection of another nation’s government, they generally flow into urban areas. The impact of this flow on cities and on the refugees, themselves, is not fully understood. This study is focused on the impact of government policy decisions on the social, legal, and economic integration of refugees within an urban environment. Investigation into this topic resulted in the development of a system dynamics model representing the city of Rotterdam, the Netherlands. The results of a designed experiment on the model indicate that economic policy directed towards refugees or specific ethnic groups results in positive trends of integration within a city system. This pilot study provides insight into the impacts of refugee flow and policy decisions within the applied context of an urban model.

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REFUGEES IN URBAN ENVIRONMENTS: SOCIAL, ECONOMIC, AND INFRASTRUCTURE IMPACTS

I. Introduction

The United Nations High Commissioner for Refugees (UNHCR) [1] has estimated the number of refugees worldwide in 2015 to be 21.3 million people. It is estimated that 1.8 million of these persons were newly displaced in 2015 [1]. Refugees, under the mandate of UNHCR, are those who migrate to other nations to seek protection against persecution [2]. These persons are not the same as internally displaced persons (estimated 40.8 million globally) or rural-urban migrants, who do not leave their country yet travel to a different locale [1]. Rural-urban migrants are not tracked by UNHCR because they are not considered to have been forcibly displaced. Generally, refugees are uprooted from their home country due to violent conflict such as war.

It is estimated that 60% of refugees worldwide live in an urban environment; the majority of these urban dwellers are living in private residences or refugee collective centers [1]. The large number of urban refugees has led policy makers to question the impact that refugees have on the city in which they reside. Is the job market resilient to a flood of refugees? A source of new labor increases competition for jobs within the employment system, potentially depressing wages. These new laborers can also fill shortages in certain industries. Refugees who do not speak the language of the host country will likely not be able to fully utilize their education and job-skills, leading to underemployment and unemployment. The impact of refugee flow on economics is related to the housing market within a city.

Is the housing market able to absorb the increase in population from refugees? The trend of populations moving into urban areas is known as “urbanization.” Urbanization has increased to the point where in 2007, for the first time in history, the global urban population outnumbered the global rural population [3]. As urbanization increases to an estimated 66% by 2050, the populations of cities are predicted to swell [3]. The literature that addresses urbanization and migration are generally concerned with internal, rural-urban migration processes and the economic impact of the migration [4]–[6]. The research presented in this thesis attempts to bring more understanding to the impact of refugee flow on city infrastructure.

Consequences of refugee migration should also be viewed from the perspective of the refugees themselves. Refugees migrate to another nation under stressful circumstances, with no job, an insecure living situation, and potentially no legal status. They often face discrimination from some members of the host population [7]. There is a large social toll that is taken on the refugees while living in the asylum of a host. Their movement is often restricted and their rights limited while the host nation works to integrate them [8]. Refugees are concerned about the same issues that city planners and politicians are: jobs and housing [9]. How are refugees going to be able to provide for and house their families? If the job market and housing markets are not able to absorb the influx of refugees, then many will be left homeless and jobless. Refugees who do not speak the language of their host nation and cannot find a secure living space or a job are vulnerable. This vulnerability is worsened by discrimination from the host population; refugees who do not feel integrated into their communities may feel victimized [10]. Even in an amiable community, refugees and other migrants may not desire to coalesce into their new communities. The concepts of integration and economic and social outcomes are explored further in the literature review chapter.

Much of the literature concerning refugees and migrant populations is found in the fields of sociology and economics. An article by Phillimore and Goodson [11] aptly describes the dual nature of refugee impact on the host nation and the refugees themselves. Phillimore and Goodson [11] along with other authors [12]–[14] recommend refugee policies and explore the impact of displacement on refugees. These studies are well-founded in the literature but, at no fault of the authors, are qualitative in nature and lack analytical rigor. Data availability is a significant problem in the attempt to analyze refugees; many persons are not tracked accurately and certain concepts, such as integration, are difficult to quantify. The economic studies concerning migrant populations are largely focused on immigrant characteristics and their impact on economic outcomes of the migrants themselves [15], [16]. These studies help to inform the research presented in this thesis about the quantitative relationship between migrants and economic outcomes; however, these and other studies are only a part of the information needed to describe refugee integration and impact on cities.

The study of ethnic enclaves is a promising vein of research in quantifying integration of migrants. Various studies that identify the causes of ethnic enclave formation address the choices of the ethnic minority [17], [18]. Sociological and economic research explains the impacts of living within an ethnic enclave on economic and social integration [19], [20]. These and other studies help to inform the research presented in this thesis about the interactions between refugee populations and the cities into which they migrate.

The Department of Defense is especially concerned with the future of large cities. Urban environments can be breeding grounds for terrorists, especially in areas where the populace is, or perceives itself as, marginalized. Ethnic enclaves can socially and economically isolate persons from the community at large, leading to a potential for refugee victimhood (real or perceived) and facilitate recruitment by radicals [21]. Cities by themselves affect global security; senior Department of Defense leaders identify cities as economic and social centers (e.g., New York, Tokyo, and Lagos) that makes them critical to both present and future global security [22]. Unemployment, competition for resources, and feelings of victimization are drivers of instability within a city [23]. All are likely outcomes of refugee flow into large cities with poor or insufficient infrastructure and planning to deal with an increase in population. Sudden pressure can destabilize a nation or a region. Various publications discuss cities as being centers for future conflict [24], [25]. If cities are to be understood, then the impact of refugee flow into them must be understood.

The Department of Defense has a vested interest in the impact of refugee flow because of the potential impact on global security and the effects of Overseas Contingency Operations and other foreign conflicts. Of the 21.3 million estimated refugees worldwide (there are likely more because of pending applications for asylum and the difficulty of tracking refugees), 16.1 million are protected under the UNHCR mandate; the remaining 5.2 million are Palestinian refugees who are protected by a separate United Nations commission [1]. The following three countries of origin comprise 53% of the refugees currently under UNHCR mandate: Syria (4.9 million), Afghanistan (2.7 million), and Somalia (1.1 million) [1]. Afghanistan and Iraq have been in the top twenty countries of origin for refugees for the past 36 years; Afghanistan has been the world leader for 33 out 36 years [1]. Recently, because of the destabilizing effects of a civil war and armed conflict on multiple fronts, Syria ranks first in refugee country of origin. These countries comprise a region in which many of the past decade's Department of Defense operations have been conducted. The United States and the Department of Defense are also interested in migration from these war-torn areas into Europe, North America, and other areas around the world. Understanding the impact of refugee flow on host nations is imperative to understanding more about the impact and direction of U.S. military and foreign policy.

The field of operations research offers methods for analyzing the phenomena associated with refugee flow, ethnic enclaves, and city infrastructure. The research presented within this thesis is an attempt to add breadth and value to the field of refugee studies through the use of modeling and simulation. To demonstrate these concepts, a model resembling the city of Rotterdam has been developed to investigate the impact of policy efforts. The Netherlands was chosen as the setting for this thesis' model for several reasons: structured city systems, administratively defined city areas, data availability, and the literature review revealed a model from which this thesis builds upon.

The following chapters in this thesis include: the relevant research from refugee studies, sociology, economics, and system dynamics; information specific to the Netherlands and its systems that are included in the model; the methodology used to model and validate the system; analysis of the results of the system dynamics model; and conclusions about the nature of the city system. Each chapter's contents are described in the remaining paragraphs.

The literature review chapter is organized into sections that build upon each other. Issues concerning refugees and studies about refugee migration and outcomes are reviewed first. Integration and ethnic enclaves are discussed next. The last sections describe cities, urbanization, and city modeling.

Following the literature review chapter is a chapter on immigration and refugee issues as they apply to the Netherlands. Regional differences for outcomes of refugees necessitate a clear understanding of the immigration history of the Netherlands and its current immigration policies.

A detailed description of the system model is located in the model development chapter. The pertinent subsystems selected for the model were Land Use, Job Market, Government, People, Education, Legal, and Social. The model in this thesis is an extension of the spatial urban dynamics model by Sanders and Sanders [26]; this study's model is named the Urban Dynamics Refugee Integration (UDRI) model. The UDRI model was verified and validated using recommendations from system dynamics literature and empirical data from Dutch national sources. The Dutch Central Bureau of Statistics (CBS) maintains public databases with information about cities in the Netherlands at the neighborhood level. This study has utilized the relevant, available data about different districts within the city of Rotterdam. Where there is no data available at the city or neighborhood level, national level statistics have been used. The use and treatment of data is discussed in the model development chapter.

Two designed experiments were used to evaluate the effect of actionable inputs on the integration of refugees and ethnic groups within the city system. The policy experiments are only a small sample of the possible uses of the UDRI model for exploration and analysis.

The analysis chapter contains results of the designed experiments and discussion of the effect of policies on the measures of integration. The results of the experiments are the foundation from which the conclusions and recommendations chapter is built. Conclusions, limitations, recommendations for future research, and significance of this study are all discussed in the conclusions and recommendations chapter.

This thesis is a preliminary study of the quantitative interrelationships between refugees and native populations in an urban system. Although the model has been built to resemble the city of Rotterdam, the Netherlands the quantitative results of this thesis are not intended to be prescriptive or predictive in nature. This thesis proposes to examine and investigate changes to a city system with the introduction of new inhabitants, specifically refugees. The intent of this research is to provide insights into the interconnected systems of a city and trends of integration measures associated with varying policy inputs to the system.

Questions addressed in this research are:

1. Which factors are the drivers of integration in a city system?
2. What are the effects of changing assumptions on city system behavior?
3. Which government policies are best suited to address problems with integration?

II. Literature Review

Overview

This chapter presents a review of literature that frames the problem and outlines methods used previously to solve similar problems. Definitions of terms are established throughout this chapter to aid in clarity. First, refugees are discussed. Following is a description of cities and urbanization; the motivations for building city models and techniques used to do so are reviewed. Lastly, the processes for validation of systems dynamics model are explained. The topics of research in this thesis are highly interrelated; however, care was taken to segregate the sections into distinct parts. Each section of this chapter builds upon the sections before them to frame the full extent of the problem.

Refugee Definition

The generally accepted legal definition of refugee is based upon the United Nations 1951 Convention Relating to the Status of Refugees, with additional clarification from the 1967 Protocol Relating to the Status of Refugees Resolution, and ratification from Resolution 2198 (XXI) adopted by the United Nations General Assembly.

The 1951 Convention Relating to the Status of Refugees was convened in response to the increase of displaced persons as a result of World War II and the lack of a consistent international protocol. According to the 1951 Convention a refugee is:

> someone who is unable or unwilling to return to their country of origin owing to a well-founded fear of being persecuted for reasons of race, religion, nationality, membership of a particular social group, or political opinion [2, p. 3].

In the text of the Convention [2] the definition of refugee only applied to those who had a well-founded fear of persecution as a result of events occurring prior to 1 January 1951. This convention was in place until the UNHCR and their international partners recognized that a permanent definition of refugee was necessary to ensure the protection of displaced persons irrespective of the time cutoff of 1 January 1951. The ever-changing global landscape required an abiding definition of refugee that would not need to be regularly updated. The 1967 Protocol and Resolution 2198 (XXI) [2] updated the previously quoted UNHCR definition of refugee to remove the time demarcation as a distinguishing factor; this thesis uses the term refugee to indicate those who are defined according to the 1967 Protocol.

Refugee Situation

Understanding the issues surrounding refugees requires knowledge of the sheer size of the situation. UNHCR estimates that at the end of 2015 there were 65.3 million displaced persons worldwide [1]. The number of refugees, as defined by the UNHCR and this thesis, was estimated to be 21.3 million persons worldwide; the actual number is likely higher because there were 3.2 million requests for asylum that had not been adjudicated by the end of the reporting period [1]. The UNHCR report entitled "Global Trends, Forced Displacement in 2015" is a description of the current global state of displaced persons. Within the UNHCR report [1], data is presented about the "population of concern." According to the UNHCR, the population of concern is comprised of refugees, asylum seekers, internally displaced persons, returnees and stateless persons. Asylum seekers are those who have applied for protection in a country different from their one of origin and have not received determination on their refugee status prior to the end of the reporting period set by the UNHCR. Internally displaced persons are similar to refugees, except they have not crossed international borders. Returnees are those who were previously refugees or internally displaced persons but have since returned back to the place from which they were displaced. Stateless persons are not considered to be citizens of any nation under the operation of the nation's law. The UNHCR 2015 estimate of forcibly displaced persons also includes those who are in refugee-like situations, internally displaced person-like situations, and others who do not fall into any category of the population of concern but are extended protection and assistance services by the UNHCR [1]. Although the plight of all persons who comprise the population of concern is serious, refugees are often in more peril than those in the other categories. This is due to their reliance on a foreign government's protection.

Most countries have a well-defined process by which refugees apply for asylum when they arrive. The particulars may differ, but the general steps for asylum application include: arrival at border or port, submission to border authority, request for asylum, and evaluation of asylum status [27]. During this entire process, refugees are entirely dependent on the protection of a government of which they are not a citizen; this makes them especially vulnerable. Their reliance on foreign government assistance also makes refugees a special concern to politicians. These characteristics are some of the motivations for studying refugees.

Refugee Studies

Previous research on refugees largely focuses on migration over international borders or economic and social outcomes of refugees. Researchers use global economic and sociological theories to posit the causes and impacts of refugee movement. Some of the studies conducted are solely descriptive in nature; there is value and insight gained from simply reporting the numbers of refugees in particular regions and their origins. The UNHCR report "Global Trends, Forced Displacement in 2015" is the best example of a descriptive study that collects data from numerous sources all over the world to provide situational awareness of refugee movement. A study from the World Bank [28] about the state of forced displacement in Europe and Central Asia shows a more narrow focus with information specific to development challenges associated with refugees in the region. Both the UNHCR [1] and World Bank [28] reports make recommendations on how best to ease the tensions that arise from refugee movement: social, economic, and otherwise. These recommendations depend on whether or not a nation abides by a particular international law or agreement as well as the current political situation within each country.

Beyond descriptive research, there are studies that attempt to predict refugee migration. Long term migration flows for each member country of the European Union are forecasted by Bijak, Kupiszewski, and Kicinger [29]. Although the study is not exclusively focused on refugees, the influx of refugees into Europe is a major consideration for the authors' predictions. The authors report a range of probable migration rates into each of the European Union member countries. A range estimate is more useful than a point estimate because of the uncertain circumstances that cause certain forms of migration. Refugee migration is especially subject to uncertainty because the conditions that spur the flight of displaced persons can form within days; a war or armed conflict could breakout and instantaneously create a new wave of refugees. Migration, let alone refugee migration, is difficult to predict and therefore difficult to prepare for.

Another study on migration in Europe by van der Gaag *et al* [30], conducted on behalf of Eurostat, utilized national and European Union datasets to develop internal migration (within each country) models to inform population projections. Two models were constructed: one model for predicting the rate of out migration of each region, and another for predicting the destination of migrants. The authors suggest that the important factors for predicting the internal migration rate for a particular region are age, sex, GDP per capita, unemployment rate, and population density [30]. The purpose of the research in this study was to provide a generalized method for predicting internal migration rates for European countries. When the study was conducted, many of the countries in the European Union did not have the recommended time-series, demographic, and/or origin-destination data collected (either by Eurostat or their own national statistical office). Therefore, only four countries (the Netherlands, Spain, Sweden, and the United Kingdom) had sufficient data to specify a model [30]. Each of these countries had a different specification of the migration model to account for cultural differences. Nonetheless, the generalized approach for building an internal migration model, and identifying the characteristics that drive it, was shown to be sound through validation with empirical data. The demographic and socio-economic factors used in van der Gaag *et al* [30] are represented in the model proposed in this thesis.

Other studies on refugees include research in a region or locale that focus on social and economic outcomes of a specific group of refugees. A common technique of studies that focus on social outcomes of refugees is to use surveys or interviews. In a report published by the Scottish Refugee Council in 2013, some refugees reported feelings of discrimination and not being welcome in Scotland [31]. The persons who are not ethnically similar to Scottish persons experienced discrimination more often than others who are ethnically closer to the Scots [31]. Not all of the comments made were negative (respondents were prompted with questions about the best and worst thing about living in Scotland). Nonetheless, the reports of discrimination and uneasy feelings indicate that refugees face difficulty with social adaptation into their host nation's society.

A comprehensive study of discrimination and social adaptation of refugee youths conducted in Denmark concluded that age, ethnicity, and sex were factors in predicting the amount of discrimination faced [10]. The authors used a structural equation model (SEM) to specify the relationships between observed and latent variables; the parameters of the SEM, demographic factors, discrimination and social adaptation, were shown to be statistically significant. Discrimination was associated with social adaptation and its measures (internalizing behaviors and externalizing behaviors) [10]. The conclusions of the research in the Danish study [10] indicate that for Middle-Eastern youths in exile in high-income countries, there are problems with social adaptation into the host nation society.

Economic outcomes of refugees are easier to measure than social outcomes of refugees because of the numerical data associated with economic outcomes (e.g., earnings and employment). The economic outcomes reported by Mulvey [31] are largely descriptive in nature. The report suggests that the majority of refugees are underemployed. The types of work that refugees had done in their home country were more diverse than the mostly menial employment they had in Scotland [31]. The barriers for employment were lack of recognition of refugee skills by Scottish employers and poor English language skills of refugees [31]. Data collected on the earnings of the refugees showed that refugees were suffering from financial hardship because of low wages and job insecurity [31].

A cross-cultural study on economic outcomes of refugees in Canada and Sweden by Bevelander and Pendakur [16] concluded that important factors in explaining employment and earnings of refugees were sex, immigrant class, country of origin, and host nation. Immigrant class is a designation of whether the refugee has arrived for family reunion purposes (i.e., a relative already lives in host nation), the refugee has arrived by government assistance, or if the refugee has arrived for asylum purposes. Bevelander and Pendakur [16] used weighted regression analysis to compare the earnings and employment outcomes across the two countries and the immigrant class. The regression models specified demonstrated that refugees from the former Yugoslavia had better earnings and employment outcomes than those from Iran, Iraq, and Afghanistan [16]. The authors posit that the reason for better outcomes for Yugoslavian refugees was the relatively larger co-ethnic population in Canada and Sweden [16]. If there is a large group of established persons in a host nation with the same ethnicity as arriving refugees, the expected economic outcomes for those refugees is higher. The presence of a large co-ethnic population provides immigrants with access to ethnic networks. The concept of ethnic networks is discussed further in the section on ethnic enclaves. Refugees in this study also tended to have better labor market performance than family reunion migrants because refugees received government assistance (i.e., language programs and other services) [16].

Although outcomes for refugees depend on regional differences, several common themes exist among the studies and serve to inform the research presented in this thesis. Specific studies on outcomes of refugees in the Netherlands are addressed in the following chapter. The research on outcomes of refugees is similar in nature to studying integration of refugees. Outcomes research typically does not have a standard against which to compare refugees. Integration research is generally more focused on whether or not refugees have met certain economic and social benchmarks.

Refugee Integration

Once refugees arrive to a new locale, how they integrate into their community becomes an issue of greatest concern. Host nations have varied policies for dealing with refugees. Italy is an example of a country that does not have a comprehensive national-level strategy for refugee integration [32]. The lack of policy has led to self-organizing systems of integration within the Italian society. Integration is not administered by the government. The organic encounters between refugees and the native population which determines what integration looks like in these nations [32]. There are countries, such as the Netherlands, with structured processes and detailed programs for refugee integration [33], [34]. Dutch national-level policies are executed at the provincial and municipal levels. Specifics of the Netherlands integration process are discussed in the next chapter.

Regardless of the policy, integration is a common topic in the study of refugees and migration.

Integration is a complex concept that has varying definitions depending on the context in which it is used. This thesis applies the UNHCR definition of local integration when employing the term integration. Local integration is one of the durable solutions as defined by the UNHCR. A durable solution is one seen as beneficial to the refugees, host nations, and potentially to the origin nations if repatriation is the solution.

Local integration is a three-faceted process, combining legal, economic, and social aspects [8]. Legal integration is the process by which refugees gain rights akin to those of the citizens of the host country. Not all legal rights are guaranteed to refugees; refugees may not be able to vote in elections without first becoming a citizen of the host country. Other legal rights, such as freedom of movement and the ability to participate in the labor market, which are important to establishing near parity in the legal status of refugees to the host nation, may be restricted. Inclusion of migrant youth in the education system is another important step in legal integration.

Economic integration is the process by which refugees come to the same standard of living and have the same economic opportunities as citizens of the host nation. A refugee would be said to be economically integrated if they find gainful employment and a residence. Refugees are fully economically integrated if they are able to achieve the same level of employment as a native citizen if they have the equivalent level of training (e.g., a refugee who was a doctor in their country of origin should be able to achieve certification and have access to requisite employment in their host country).

Social integration is a two-fold process by which the host nation population accepts the refugees and the refugees adopt the culture of the host nation. Beyond official policy or programs, there are varying public sentiments regarding refugees. Some countries are liberal in their acceptance of immigrating persons regardless of origin or legal status. Other countries are much more resistant to outsiders migrating to their country. Regardless of the opinion of the host nation native population, refugees themselves have proclivities for integration [11]. There are groups of persons who desire to adopt the culture of their new home (i.e., assimilation). There are other persons who wish to retain their culture or do not wish to embrace the prevailing culture (i.e., separation). There are many aspects of culture that affect the social integration and changing culture of refugees. Social integration is a two-way process that is different from assimilation.

Assimilation is a process whereby newcomers in a society change to match the prevailing cultural norms of society. Of course, there is some level of assimilation in the process of integration (e.g., language). Nonetheless, individuals are not required to lose their cultural heritage to be integrated. Society is comprised of many individuals. Culture is made from the prevailing characteristics of the society at large. Therefore, it is expected that there will be individuals with varying degrees of likeness to the cultural norms. The culture of a society can change with the addition of newcomers who are significantly different from the current culture. Social integration is a mixture of individuals with differences. Assimilation is a transformation of newcomers to become like the locals.

Another aspect of refugee integration is the distribution of where people live and work. This is closely related to economic and social integration. Even if refugees attain employment and are welcomed into the host nation's culture, they may not necessarily be living in the same area within the city. This facet of integration warrants its own discussion in the following section because of its relation to cities and urban studies.

Ethnic Enclaves

An ethnic enclave is a residential or commercial area with a high concentration of residences or businesses that are occupied by persons of an ethnicity different than the majority population [17]. The causes of enclave formation vary according to countries and regions. Ethnic enclaves within cities in the United States that have a legacy of racial segregation do not have the same causes of formation as multi-cultural enclaves within Europe [35]. Nevertheless, a primary reason for enclave persistence is cultural in nature; arriving individuals, especially ethnic minorities, tend to make residential choices based on the cultural composition of neighborhoods within the city [15], [17]. The choice of location can significantly affect the social and economic outcomes of immigrants, both negatively and positively.

Persons of ethnic minority who live within an ethnic enclave tend to be economically disadvantaged [15]. This disadvantage is complex in nature. Economic disadvantage can be a result of poor skills in the native language of the host nation [36]. Research has found that living within an ethnic enclave is detrimental to improving native language skills of immigrants [19], [20]. Furthermore, it has been shown that immigrant residential choices are partly based on language skill; immigrants with low proficiency in the native language tend to live within co-ethnic neighborhoods [18]. This means that immigrants with poor language skills are likely to choose to live in an ethnic enclave where their language proficiency is often negatively affected. This choice is even made with the knowledge of a high unemployment within ethnic enclaves. Immigrants without the ability to speak the host nation language almost have no choice other than to move into an ethnic enclave in order to fit in and function [18].

Another cause of economic disadvantage is that areas of high ethnic concentration tend to be areas with low income and economic development [37]. Arriving immigrants tend to choose places to live with those of similar ethnicity and economic status; low-income, co-ethnic persons coalesce and create (or perpetuate the existence of) disadvantaged neighborhoods [37]. A lack of language or job skills can lead to isolation and an inability to move outside of the community, continuing the cycle of disadvantage for ethnic minorities. The isolation of immigrants within an ethnic enclave leads to differing social outcomes.

The high co-ethnic concentration of residential areas can have a positive social impact on immigrants. Access to a network of individuals who have been established in the country who speak the same language as the immigrants is helpful for finding employment [20]; but this benefit generally extends only to jobs within the enclave or ethnic network [15]. Relying solely on the social network of an ethnic enclave to find employment can increase competition for those few jobs and lead to higher than average unemployment [18].

The positive initial impacts on the social integration of immigrants are small in comparison to the persistent isolation effects of living within an ethnic enclave. For immigrants living and working with persons who do not speak the native language of a host nation, there is less incentive to learn the native language and, perhaps, customs [20]. The reliance on the immigrant's own language leads to a slower learning process of the native language. As the immigrant's language skills increase, they tend to move residences to areas of lower ethnic concentration. An increase in native language skills increases the employment opportunities for immigrants and increases their social integration [18]. Ability to speak in the host nation language and communicate with the native population has been identified as a critical factor for social integration [10], [37], [38].

The specific impact of ethnic enclaves depends on the culture of the host nation as well as integration and asylum policies. Literature specific to ethnic enclaves, integration and, government policy in the Netherlands is discussed in the next chapter.

The realities of how a majority of refugees migrate into and live in cities dictate that the impact the refugees have on host nations should be investigated at the city level. Global trends of urbanization and DoD interest in cities both support the case for a city as the appropriate system for analysis in this thesis.

City Definition

It is important for the sake of clarity to define the term city as used in this research. The United Nations Department of Economic and Social Affairs (UNDESA), Population Division, has identified four types of criteria used to define urban areas with 11 different combinations of criteria used in 233 countries: administrative, economic, population size and density, and urban characteristics [3]. The different definitions of a city range from a single criterion to combinations of all four criteria. The definition of a city used in this thesis is the administrative definition of an incorporated metropolitan area. The research questions at the end of the previous chapter require a strict demarcation of those living within the city and those living elsewhere. A city that is defined administratively contains all of the subsystems of interest (e.g., jobs, housing, and education). Other city definitions are not necessarily sufficient. A city that is defined by urban characteristics might not contain an education system. Cities defined by population size or density might not have a regulated asylum process. Economically defined cities might not have consistent housing or land use. The most frequent definition of a city (used by 27.9% of countries) is administrative determination as the sole criterion [3]. Although population is used in conjunction with other criteria more frequently than administrative (37.3% compared to 25.8%), the threshold for population varies among countries [3]. Deciding how many people must live in a place to be considered a city is subjective in nature. However, a city with an administrative governance is not subjective; there are regulations and laws in place that determine what areas are included in the city and what areas are not. There are likely demarcations of certain regions or neighborhoods within an administratively defined city, which is an important characteristic for the analysis in this thesis.

Urbanization

Cities around the world are in size and number. As of 2007, it is estimated that globally, for the first time, more people live in urban areas than in rural areas [3]. More than half of urban dwellers live in settlements with less than 500,000 inhabitants; the number of these relatively small settlements is increasing on a yearly basis [3]. Not only are cities growing in number, but the size of the largest cities is increasing. One in eight urban dwellers live in a megacity (i.e., an urban agglomeration with a population of more than 10 million people) [3]. The number of megacities has increased from 10 in 1990 to 28 in 2015 [3]. Although the rates of urbanization differ by region and even within countries, the global level of urbanization is expected to continue increasing.

Urbanization is the process by which persons move into urban areas or the process by which land areas become classified as urban. According to Buhaug and Urdal [23], the three phenomena that cause urbanization are natural growth, rural–urban migration, and reclassification of areas from rural to urban. Natural growth occurs when the population of a city increases through natural, reproductive means -- the growth comes internally. Reclassification is the process of a governmental authority classifying areas as urban that were not previously so designated. The designation of areas being rural or urban can change and vary depending on which definition the government chooses and can change over time [3]. The migration of persons from rural to urban areas is one that is of major concern to government organizations and the Department of Defense. Reclassification is under the direct control of the ruling government. Rural-urban migration is a more complex issue. The reasons for this type of migration and the implications of it are often not straightforward.

Literature considering rural to urban migration is largely from the perspective of agricultural labor sectors. There are various “push” and “pull” factors that affect the rate of rural-urban migration [6]. Push factors are circumstances exogenous to the city that cause people to move from their homes to the city. Examples of push factors include drought in rural areas, lack of rural jobs, and so forth. Pull factors are endogenous characteristics of a city that make a city more desirable to live in. The estimation of potential earnings differential between rural and urban areas and the probability of gaining employment are important pull factors for rural-urban migration [4], [6]. Even when faced with rising urban unemployment, people continue to migrate into cities at unprecedented rates [3], [6]. This movement indicates the pull of the city may be stronger than the push from rural areas. The perceived attractiveness of urban employment opportunities overwhelms its actual employment prospects.

Refugee migration and rural-urban migration are similar; although, the effect of refugee migration is smaller in magnitude, so it is not a driver of urbanization. Outsiders who move from the countryside to metropolitan areas are not necessarily the same as those who have been living inside the city for generations. This outsider mentality is important for considering how refugees act within a city. Nonetheless, the prevailing reasons that spur refugee migration are different from rural-urban migration. Although the traditional push and pull factors are present to facilitate refugee migration, the attractiveness of cities is not the impetus that spurs refugee flight. The dominant push factors of acute problems such as war predominate other reasons to leave for refugees [39]. The pull factors that draw refugees to a specific locale include leniency for asylum seekers, large groups of like persons, and perceived potential for sustainable livelihood [39]. Refugees may travel to a neighboring country for immediate safety, or they may travel great distances to reunite with family or to obtain expected better outcomes in a different country.

Refugees may not have a choice of where they live within a country. This could be a result of government policy or just a consequence of where and when they arrive. Refugees who apply for asylum may have their movement restricted to a camp or specific municipality [12]. These factors change how refugees flow across and within countries. To further understand how refugees interact with the markets of the cities where they live, various city models and the motivations for making them are explored.

City Models

City models are created for a number of reasons. Policy makers may be looking for information on the effect of urban planning decisions. Social scientists are interested in the interactions between denizens of a city. The characteristic of interest is a driving factor in the modeling choice. Three general focus areas for city modeling are the persons within a city, the land use of the city, and the systems that interact in the city. Each of these areas have been researched previously and modeled with an array of techniques. The following sections review research on modeling cities, organized by focus area.

Population and Social Dynamics.

Cities have structure and form; however, one of the least structured components of a city are the persons who live within it. For as many individuals as exist in a place, there may be just as many differing social groups. If the aim of a research endeavor is to explain social dynamics of a city, an appropriate modeling choice would be to use techniques that allow for the fluid formation and change of groups according to characteristics of individuals.

Cellular automata and agent-based modeling are two related techniques that are useful for analyzing population growth and social dynamics. Cellular automata models represent a grid of cells that have a state and characteristics. The model is initiated with each cell being in a particular state. Small models are generally described by binary states. Each cell has a set of rules for whether or not it will transition to a different state in the next time step. The rules for transitioning are based upon the state of the cell and its neighboring states. Simple rules can lead to complex system behaviors over time. Figure 1 shows the rules for a two-dimensional cellular automata model; the state change rule is determined by the state of a cell and its neighbor to the left and right. At each time step the cell directly beneath a cell changes states (or remains in the same state) according to the rules in Figure 1.

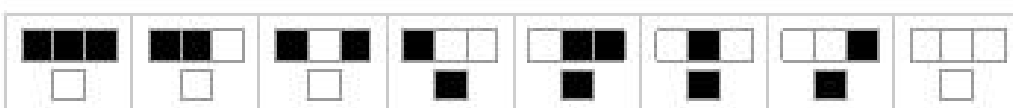

Figure 1: Cellular automata rule set

Figure 2 shows the state of the model at time steps 0, 1, and 5. Time step 0 represents the model at initialization with one black cell. The end result is a complex structure of cell states that evolved from simple rules.

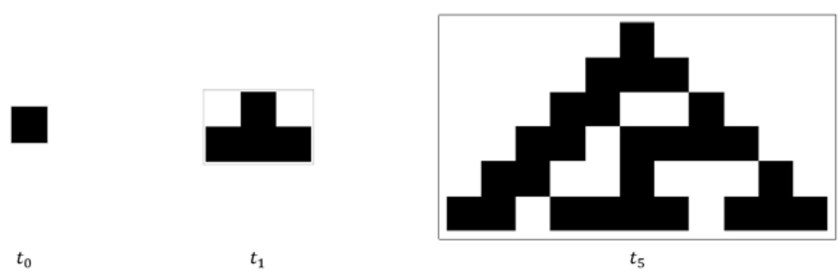

Figure 2: Cellular automata model at time steps 0, 1, and 5

Agent-based models are similar to cellular automata models in that entities (i.e., agents) in a system will "act" according to rules for interaction with other agents. The agents are described by properties. Each agent interacts with other agents according to its own properties, the properties of the other agents, and the system at large. The rules for these interactions are generally simple. This technique is commonly used in conjunction with discrete event simulation wherein the state of the system changes according to the interactions between agents at time steps.

Benenson [40] describes a methodology for modeling population dynamics in a city. The multiple agent approach, as defined by the author, is a combination of cellular automata and agent based modeling. The two layers of Benenson's model were housing infrastructure and free agent. In the housing layer, the cells were classified as either occupied or not occupied. The housing cell characteristics are affected by the economic status of the cell's resident and the economic status of the neighboring cells. The free agent layer, or people layer, is characterized by individuals with economic and cultural characteristics. The agents can decide whether to move to an available housing cell, stay in the same housing cell, or leave the system at each time step. Benenson classifies an agent's cultural characteristics using a binary vector. A culture vector of length k could result in as many as 2^k different cultural identities. The agents choose to move based on the value and availability of housing cells as well as the similarity between themselves and their neighbors economic and cultural characteristics (i.e., economic tension and cognitive dissonance, respectively) [40]. The characteristics of agents in this model can change depending on the characteristics of neighboring agents and the agents' movement choices. Agents can leave the system, and new agents can move into the city depending on housing availability. While the model in this thesis uses a different technique than the model used by Benenson [40], the concepts of what motivates individuals to move within a city informed development of the model in this thesis. Persons in a city choose to live in certain locations based upon availability and their own economic status in addition to the cultural identity and economic status of their neighbors.

A strength of population and social dynamic models is that they are fluid. Such models allow for the evolution of a complex system. Complexity is a characteristic of human systems and natural systems. These models can represent social interaction and population dynamics within a city but cannot describe how the city is structured or its layout unless physical, geographic factors are considered.

Land Use.

Some of the most popular techniques for modeling and predicting land use require the use of satellite or aerial imagery (both visible and non-visible spectrum). A Geographic Information System (GIS) is the interface through which the imagery and other data is input, stored, and manipulated, and reports are generated [41]. Land use research using GIS is an amalgamation of numerous fields of study including geography, remote sensing, statistics, and operations research [41]. GIS allows for implementation of mathematical models that relate variables in the dataset to predict land use change and model the evolution of urban sprawl.

Spectrum imagery focused research has been established as an accurate way to model city growth and classification of urban areas. Urban classification models of 27 megacities were built and verified by Esch, Taubenbock, Felbier, Heldens, Wiesner, and Dech [42] to demonstrate the effectiveness of Earth observation satellite imagery to detect sprawl and urban growth. The methodology used in this study consisted only of spectrum analysis of imagery pixels and remote sensing classification techniques to achieve an overall classification accuracy of 90.5%. Other models for land use utilize GIS and incorporate economic or other city features to predict land use change and urban growth.

Most of the cities that are being studied for urban growth are those in Africa and Asia because these regions have the fastest rates of urbanization [3]. Nong and Du [43] constructed a model of Jiayu county of Hubei province, China with data from GIS, demographic, and economic sources. The county was discretized into 100 meter square cells, each classified by land use as urban or non-urban. Using logistic regression models the researchers produced a land use change probability map that shows the probability that a cell was going to change from non-urban to urban land. The model's classification accuracy, as compared to actual land use change, resulted in an area under the receiver operating characteristic (ROC) curve of 0.891 [43]. This result indicates that economic and demographic sources are sufficient for predicting land use changes. Nong and Du's model [43] uses characteristics of each cell to determine whether or not it is likely to transition from non-urban to urban. These cells are treated as independent units; this assumption ignores the interaction between characteristics of neighboring areas.

Barredo and Demicheli [44] from the European Commission Monitoring Land Cover/Use Dynamics (MOLAND) Project, used cellular automata to model the city of Lagos, Nigeria and predicted future land use. The model of Lagos included several classifications of land use and various stochastic processes to accurately model the complexity and uncertainty of the social and economic process of city growth. Certain cells in the city were in unchangeable states but included in the model because they contribute to the dynamics of other cells in the area. Barredo and Demicheli [44] predict that by 2020, Lagos will grow to cover an area more than three times greater than the area of Paris. The specific results of the simulation are not the most concerning; rather, it is the prediction that the city will grow so rapidly that urban planning must become a top issue for the Nigerian government.

Research focused on land use change is primarily concerned with the way that cities grow and their physical layout. These models sometimes involve social and economic factors as a part of their specification. Land use models can indicate whether or not a piece of land is being used for industry, but they do not model how the industry functions within the city.

Infrastructure.

Understanding the infrastructure of a city requires an understanding of how a city functions with respect to its parts. Forrester [45], in his text *Urban Dynamics*, described a city as a system with interacting subsystems. Any particular subsystem is connected to other subsystems through the interaction of system components. A practical example is the interaction between the jobs and people in a city. Job availability attracts persons to move to a certain area of the city. Persons moving to other areas of the city can create job availability. This simple interaction does not capture the full extent of the interrelationships between jobs and people within a city; nevertheless, it does illustrate dependency as a result of interconnected subsystems. A technique commonly used to explain the behavior of systems is system dynamics.

The generalized form of a system dynamics model is a closed-boundary system comprised of feedback loops [45]. The closed-boundary aspect is not unique to system dynamics models; a closed boundary allows for the inclusion of subsystems of interest and the exclusion of less important aspects of a system. A feedback loop is made from level (state) variable(s) and rate(s) (flows) [45]. The level and rate inform each other, resulting in the loop form. Figure 3 shows the simplest possible feedback loop in a system dynamics model.

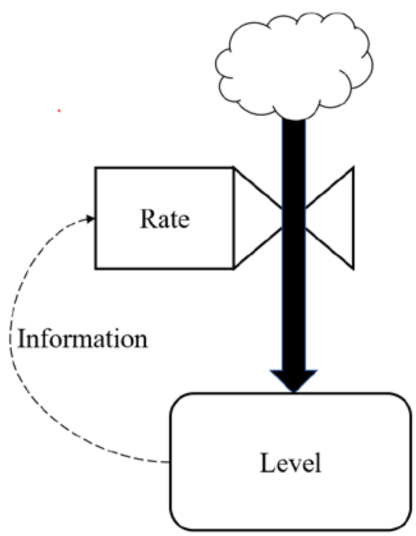

Figure 3: Simple feedback loop. Adapted from Forrester [45].

The application of system dynamics to cities was first shown by Forrester in his 1976 book *Urban Dynamics*. Forrester's model of a city was built to analyze the way that people, jobs, and housing within a city interacted and to recommend solutions to city planners for the complex problems facing aging and growing cities. The model in *Urban Dynamics* [45] (hereafter referred to as the Forrester urban model) is a generic city with three main subsystems: housing, employment, population. The population is partitioned into three different sectors that describe people's roles in the labor market:

Underemployed represent low-skill workers, Labor represents high-skill workers, and Managerial-Professional represents the administrative workers in society. People can move between sectors so these are not fixed populations [45]. These designations are made by Forrester to represent a generalization of the city's labor market. Forrester argues that modeling the specifics of any one industry causes the model to not represent the general employment trends that are of interest. The Forrester urban model captures the movement of persons into and out of the city based upon the relative attractiveness of the city to the exogenous population. This attractiveness is based upon job and housing availability, labor mobility between sectors, and other characteristics of the city [45]. Forrester's urban model does not divide the city into neighborhoods, so it does not capture the population dynamics within the city itself.

Sanders and Sanders'[26] model (referred to as the Sanders model) is an evolution of the original Forester model. This model builds upon other researchers who have improved upon the Forrester urban model. The Sanders model divides the city from Forrester's urban model into 16 different zones; each zone within the city represents a neighborhood. This change allows for the analysis of residential and employment dynamics within the city. Traditional spatial dynamics models allow for the migration of persons from one region to a neighboring region. Sanders and Sanders [26] have created a model that accounts for the movement of individuals from any zone in the city to any other zone. This spatial urban dynamics model is a more accurate representation of how people change residences in a city. The Sanders model uses the same attractiveness measure as Forrester to affect the rate of migration between zones. In addition to the attractiveness of zones, the Sanders model uses a distance metric to make zones further away seem less attractive than closer zones [26]. The addition of a distance variable is important to improve the accuracy of the spatial urban dynamics model. This thesis uses the Sanders model as a starting framework for modeling the city of Rotterdam. The specific formulation of the Sanders model is discussed further in the model development chapter of this thesis.

System dynamics is an appropriate technique for modeling the impact of refugees on a city. The interrelated topics of refugee studies, sociology, economics, and urban systems can be captured within the context of a system dynamics model. This technique also allows for intuitive modeling of the influence of qualitative factors on quantitative measures. System dynamics is excellent for modeling interactions between various systems and the complex behaviors that result from feedback loops. However, there are difficulties with verification and validation of system dynamics models, which do not apply to other simulation or mathematical models. Following is a section that discusses the unique challenges for verification and validation of system dynamics models.

Verification and Validation of System Dynamics Models.

Literature on verification and validation in the field of system dynamics generally uses the term confidence when discussing the vetting of a particular model [46], [47]. Forrester and Senge [46] and, more recently, Sterman [48] in his 2000 book, *Business Dynamics: Systems Thinking and Modeling for a Complex World*, have provided many examples of the types of tests that can and should be used to build confidence in the accuracy and usefulness of system dynamics models. A paper written by Zagonel and Corbet [47] summarizes the recommended tests from [46] and [48] and other sources of system dynamics literature into a framework of five components: system’s mapping, quantitative modeling, hypothesis testing, uncertainty analysis, and forecasting & optimization. Each of these components is derived from a phase of model building and testing. Although these categories are not necessarily mutually exclusive, Zagonel and Corbet [47] organized 24 different tests into the five different components. They also used expert judgement to determine the level of rigor involved for each test: basic, intermediate, advanced.

System's mapping is the component of system dynamics modeling that is concerned with the layout of information in a graphic manner. This includes the building of the system model with its levels, rates, and feedback loops. System's mapping validation asks questions such as: is the model built from the correct pieces? Are the pieces connected to other pieces in the correct manner?

Face validation is a test used to build confidence in the system's mapping [47]. Face validation is the process by which model components are confirmed to be consistent with descriptive knowledge of the real-world system [48]. Forrester and Senge [46] note that verifying that the model structure is present in the real-world system is different from (and easier than) establishing that the most relevant structure for the model's purpose has been selected from the real world. That is, if a model's structure is represented in the structure of the real-world system, then the model has face validity. It is a different argument to say that a modeler has not selected the most appropriate structure from the real-world system in question. After establishing that the structure of the system dynamics model is correct, validation of the quantitative nature of the model can be conducted.

Quantitative modeling is the component of validation that examines the way in which the model's parts interact mathematically. During this stage of validation, questions asked by modelers include: does the model conform to real-world behaviors, such as conservation laws [47]? Does the model reproduce real-world behavior without exogenous inputs providing predetermined responses [47]?

Basic quantitative modeling validation tests include integration error and dimensional consistency [47]. Integration error checks whether or not the model is sensitive to the time-step or numerical integration method [47]. If a change in the time-step produces different model behavior, then the model is subject to integration error. Dimensional consistency is analysis of the model equations. If all of the model equations have consistent dimensions without parameters that have no real-world meaning, then the model has dimensional consistency.

More rigorous methods are required to complete validation of the quantitative modeling component. Extreme conditions tests examine how the model equations react to inputs that are on the extreme ends of possible input [47]. Extreme inputs to a city system could be no people living in a particular neighborhood or ten times the city population moving into one neighborhood. The focus for extreme conditions testing here is on the equations and how they behave when stressed. Extreme conditions are used in other components of model validation. A modeler must assess whether or not the system can reproduce real-world system behavior. Behavior reproduction is a test of the models output compared to real-world data [48].

Hypothesis testing includes methods that check the model for the components necessary for analyzing the problem of interest. Questions that modelers ask when conducting the hypothesis testing component of validation include: are the important pieces of the system present important to addressing the problem in the model [47]? Do the rules of interaction capture actor decisions in the system [47]? The hypothesis testing component is dissimilar to the previous two components of validation in that a failure of the test does not invalidate the model; rather, it validates the model. For example, in behavior anomaly tests, model assumptions are changed or removed. If the changed model produces wildly different behavior as compared to the original model, then it can be concluded that the assumption that was modified is important to the model and the attendant explanation of system behavior [47]. Naturally, this conclusion is made for a model that has been validated by other tests (i.e., reproduces behavior, face validity, and so forth).

Uncertainty analysis is the component of validation testing that aims to determine the effects of uncertainty, or randomness, on the model behavior [47]. Almost all real-world systems have some stochastic elements or influence. Very few processes or systems are strictly deterministic. To account for random behavior, many modelers will incorporate probability distributions into their model equations and parameters. Uncertainty analysis tests have similar foci to quantitative tests on numerical parameters and qualitative tests on modes of behavior. However, the objective is to determine how uncertainty about assumptions or model boundaries influence the behavior of the model. These tests refine the equations and parameters because of the introduction of uncertainty.

The final component of validation testing is forecasting and optimization. These tests focus on predicting future system behaviors and phasing of behaviors. This is only possible to do so reliably after the model has been validated and shown to be sound in the previously discussed ways. Changed-behavior tests involve implementing policy changes in the model and examining the outcome [48]. There are two general approaches to changed-behavior tests. The first approach is implementing a policy change and determining if the model behavior has changed in plausible ways [46]. The second approach implements real-world policy changes that have been made previously and comparing the resulting model behavior to the actual results of the real world system [46].

Zagonel and Corbet [47] note that determining which validation tests are appropriate (and necessary) for system dynamics models depend on the model's purpose and particular application. This thesis does not use all of the validation tests from Forrester and Senge [46] or Sterman [48] but does rely heavily on this literature and the recommended framework from Zagonel and Corbet [47]. The specific steps taken to verify and validate the model in this thesis are discussed in the model development chapter.

Summary

It is apparent that there is interest in the impact on and from refugees within cities. The causes and effects of refugee integration depend on regional differences. A case study is necessary to satisfy the requirement of regional specification. The following chapter is a description of the Netherlands in the context of refugees, labor, housing, education, and social factors.

III. The Netherlands

Overview

This chapter presents an overview of Dutch immigration policy and refugee studies. The first section explains the rationale for choosing the Netherlands as the setting for the city model. Following that is a brief history of Netherlands immigration policies. The next section is a description of the current Dutch immigration program. Subsequently, some studies that focus on the specific outcomes of refugees within the Netherlands are reviewed. Throughout this chapter and the remainder of this thesis, English long-form names of various Dutch bureaus and ministries are used; acronyms and initialisms for these organizations are in the Dutch form (e.g., Executive Agency for Education has the acronym DUO).

Selection of the Netherlands for Model

According to Sanders and Sanders [26], one of the shortcomings of their model was the lack of empirical data. They remark that the model is useful for the analysis of city systems in general; however, the model does not accurately represent any city specifically because of the use of nominal data. Sanders and Sanders [26] recommend the application of their model to a real-world city to address the criticism of their non-specific model. Throughout their text the authors refer to the city of Rotterdam, Netherlands as an example of a few of the urban dynamics phenomena; they explicitly state that no conclusions should be made about the similarity of population growth patterns between Rotterdam and their model [26]. The references to Rotterdam and the authors' connections to the Netherlands (student and faculty at Delft University of

Technology) led to an interest in the Netherlands as a location for the city in this thesis. The historic, and even more recent, political discourse about refugees and immigrants within the Netherlands indicated that an investigation into refugees within Dutch cities would surely prove to be interesting and worthwhile. Further research revealed that the administrative structure of Dutch cities and their education system were excellent fits for the use of system dynamics, thus solidifying it as the chosen location for this thesis.

The choice of a specific nation for the application of the model in this thesis also fulfills the need for region specific differences in refugee studies and outcomes. The requirements (i.e., outcomes) of the Netherlands' current integration program are explicitly clear for immigrants. The specifics of the current Dutch integration program are discussed in a later section of this chapter. The accuracy of model specification requires a knowledge about the systems being represented. The remaining sections of this chapter contain qualitative information about the Netherlands that contribute to the understanding of a Dutch city system.

Brief History of Dutch Integration Policy

Every year since 1961 (except for 1967) the Netherlands has been a net immigration country (more people immigrate in than emigrate out) [49]. The fact that persons were migrating to the Netherlands and not leaving was not rectified with national Dutch immigration policy for many years. During the 1960's and 1970's the Netherlands recruited guest workers from Southern Europe, Turkey, and Morocco to bolster their labor market [50]. These guest workers were seen as temporary additions to the Netherlands; a few guest worker policies were established to deal with accommodation and services to return immigrants to their country of origin [50]. Persons were identified by groups: either by nationality (e.g., Surinamese) or by purpose of immigration (i.e., guest worker) [51]. This language established what Scholten [51] describes as “differentialism.” The legacy of such distinctions is evident in the current method used by the Dutch government to differentiate between persons based upon ethnic origins. Under differentialist views immigrants were viewed as “others,” not as citizens, and therefore were not afforded many of the same legal rights as Dutch citizens and lacked the avenues to obtain such rights.

It was not until 1978 that the Netherlands ratified its first national policy for immigrants [51]. In 1983 the first immigrant integration policy was established [51]. The policies formulated and enacted from 1978 until 1994 that framed immigrants as ethnic or cultural minorities are collectively described as the Minorities Policy. Scholten [51] mentions that each group was encouraged to maintain their cultural identity because the socio-cultural emancipation of immigrants was believed to increase socio-economic participation. The immigrants identified as protected under the Minorities Policy included the major groups that had made up the migrant population until that point in Dutch history (Moluccans, Surinamese, and so forth) [51]. These groups were seen as permanent residents of the Netherlands; however, the national government did not change its view on the constancy of immigration. The presence of a minority population was seen as an abiding phenomenon -- immigration was not [51]. For this reason, the protections of the original Minorities Policy did not extend to groups such as Chinese and Pakistani, who were considered to be transient groups of people [51]. During the

Minorities Policy era, the Dutch government made concerted efforts to ensure the socio-cultural parity between ethnic groups.

Spurred by the poor economic outcomes of minority groups in the late 1980's, Scholten [51] mentions that the priorities of the Minorities Policy shifted to focus more heavily on socio-economic participation. The discourse of Dutch politics made another shift with the formal recognition of immigration as a constant process. Dutch lawmakers recognized that the Minorities Policy laws were not adequate to deal with a constant influx of immigrants, especially those not specified under the current laws [51]. In 1994 the Dutch government shifted from Minorities Policy to Integration Policy. Government policy was focused on individuals integrating into Dutch society instead of a policy focused on groups of people [51]. The language of Integration Policy still differentiated between groups of persons based upon ethnicity and origin [51]. The implementation of Integration Policy in the 1990's marked a shift from group focus to area focus. Policies were aimed at addressing the complex spatial, economic, and social problems of the four largest cities in the Netherlands (i.e., Amsterdam, Rotterdam, The Hague, Utrecht) [50]. Dutch language classes were introduced to increase the performance and participation of immigrants within the labor market. The Integration Policy era also saw the creation of city planning policies to address the same issues. Cities in the Netherlands contained neighborhoods with poor housing, unemployment, and socio-economic rifts between people. The areas of cities affected the most by these plights were also the areas with high concentrations of ethnic minorities [50]. These city planning policies can be considered an extension of Integration Policy because they addressed the same issues and the same people due to the interconnected nature of immigration and low socio-economic status.

In the early 2000's the Dutch government shifted from the integrationist approach to one that is more in line with assimilation. The shift came about from a combination of culturally significant events (including populist movements within the Netherlands and the 9/11 terrorist attacks) that highlighted a perceived (and potentially real) socio-cultural distance between immigrants and Dutch society [51]. The new language of the Dutch integration policy was largely focused on bridging the differences between individuals. Instead of speaking about the cultivation of one's individual culture, the laws focused on building a common identity with shared values and norms -- namely, Dutch values and norms [51]. The effects of this era are seen in the application of the current Dutch integration program.

Current Integration Program

Current Dutch integration policy appears to be a combination of socio-cultural assimilation and socio-economic integration. Beginning with the implementation of the Civic Integration Act of 2007, immigrants are required (with few exceptions) to pass an integration exam [33]. The Civic Integration Exam has changed since its inception; the current form (as of 1 Jan 2015) consists of six parts to assess the immigrant's knowledge of the Dutch language and culture: reading, listening, writing, speaking, knowledge of Dutch society, and orientation of the Dutch labor market [33]. The orientation of the Dutch labor market is the most recent addition to the exam; this portion is an assessment of how prepared the immigrant is to enter and be successful within the Dutch labor market. If potential migrants, with the exception of asylum seekers, are moving to the Netherlands to reunite with family members, they must take the Civic Integration Exam *before* traveling to the Netherlands [33].

There is another test that immigrants can take, the Dutch as a Second Language State Exam, referred to as NT2, which covers most of the requirements of the Civic Integration Exam; as of 1 Jan 2015 the NT2 must be supplemented with the knowledge of Dutch society and orientation of the Dutch labor market sections of the Civic Integration Exam [33], [34]. The NT2 is a more difficult test and is administered to provide immigrants with the opportunity to enter higher education (university equivalent) or a high-level vocational program [34]. Either one of these tests must be completed and passed within the 3-year “integration period” that starts once immigrants receive their residency permit or turn 18 [34]. A few reasons can exempt individuals from having to take either exam. These reasons include being under the age of 18, having lived in the Netherlands for eight years during the compulsory education age, or having graduated from a secondary education institution or higher institution that was taught in Dutch [33]. Other exemption criteria include nationality and evidence of previous integration certificates [33].

Persons who do not pass the Civic Integration Exam or NT2 within three years must either: request an extension of two years if there is evidence they have tried sufficiently hard or if they faced extraordinary circumstances (illiteracy, illness, and so forth); or must pay a fine and then have an additional two years to complete the requirement [34]. Immigrants who do not complete the integration requirement within the integration period (including an extension) are subject to loss of their residence permit The only group with protected residency status are asylum migrants (refugees) [34].

The current integration program of the Netherlands focuses on economic and social outcomes. Passing one of the tests indicates preparedness for the Dutch labor market and command of the Dutch language. Immigrants who learn the Dutch language are able to improve their economic and social outcomes. The definition of integration used in this thesis focuses on the three components of local integration from the UNHCR [8]: legal, economic, and social. This is for two reasons. First, the components can be measured, whether directly or by proxy, and they are largely objective. The second reason is more important to the specific application of refugees integrating in the Netherlands and is discussed in the following paragraph.

After refugees arrive and are granted asylum, they are first required to register with a municipality [52]. Refugees who complete the integration requirements are afforded rights of residents and a path to citizenship if they wish to pursue citizenship. Registering and fulfilling the integration requirement fulfills the legal aspect of integration. The number of refugees who become permanent residents or citizens can be a measure of the legal integration. The economic part of integration can be measured by the performance of refugees within the labor market. This includes the proportion of refugees in each sector of the labor market as well as the housing status of refugees. Refugees in the Netherlands have the right to a house in a municipality [53]; asylum seekers do not necessarily have the right to choose exactly where they live within a municipality. Municipalities such as Rotterdam have implemented dispersal policies in the past to evenly distribute asylum seekers to ease housing pressure [54]. Social integration can be measured by the housing dynamics and the comparison of refugees to other groups of people. Language ability is another important aspect of social integration; using the proportion of refugees and their children who are in Dutch education or who have passed an integration exam could be a measure of social integration. A looser definition of social integration might include the ability to communicate with members of the host nation, regardless of the language used. This could be the case in the Netherlands where 90% of respondents to a European Commission survey said they were able to speak English well enough to hold a conversation [55]. Even if immigrants are able to communicate with others in society, it is required they learn Dutch to be allowed residency.

The Dutch integration system can be seen through the lens of system dynamics. Incorporating it into an urban dynamics model will provide insight into the interactions of immigrants within a Dutch city system.

Refugee Studies, Netherlands

Refugee studies in the Netherlands are closely tied with the study of immigrant groups. During the transition from the Minorities Policy era to the Integration Policy era, the Dutch government restructured how information was collected on immigrant groups. It no longer focused on specific ethnic groups; but rather, it collected information on immigrants as a whole. The Netherlands' national statistics office, Central Bureau for Statistics (CBS), created a new definition of ethnic minorities; the new definition delineated between "autochtoon" (native, singular), and "allochtoon" (immigrant, singular) [56]. Allochtonen (plural form) indicated individuals who had at least one parent who was not born in the Netherlands. Persons whose parents were both born in the

Netherlands were classified as autochtonen (plural form). CBS also created a sub-division within the allochtoon category, between western allochtoon and non-western allochtoon. Western allochtonen are persons who were considered to be socio-economically and/or culturally close to the Dutch [56]. The distinction between western and non-western is not necessarily a geographic indication. Under the CBS definition western countries are defined as: all countries in Europe, (excluding the Netherlands and Turkey), North America, Indonesia, Japan, and Oceania (e.g., Australia and New Zealand) [49]. Non-western countries are defined as: all countries in Africa, Asia (except Japan and Indonesia), Latin America, and Turkey [49]. These terms have developed a negative connotation over the years since their first use by the Dutch government. Nonetheless, this thesis uses the terms autochtonen and allochtonen to refer to these groups of people because statistics have been collected according to these group definitions and refugee outcomes in the literature are differentiated by (or can be organized into) these groups. It should be noted that the distinction allochtoon does not have any implications for citizenship. First generation allochtonen are migrants to the Netherlands; second generation allochtonen are born in the Netherlands with one or more parents not being of Dutch origin. Individuals who were born in the Netherlands with at least one Dutch parent are citizens. Therefore, the number of allochtonen in any statistics database includes Dutch citizens and residents alike.

In studies of integration within the Netherlands, refugees are often grouped together with immigrants according to the groups established by CBS or by country of origin. For this reason, Dutch immigrant studies are used to inform the research in this thesis; distinctions specific to refugees are noted where applicable. The outcomes of different groups of immigrants in the Netherlands follow the same trend as immigrant outcomes in general. Immigrants of all groups, as compared to autochtonen, have higher rates of unemployment and are more likely to have lower education levels [56]. Allochtonen had also been more severely impacted (e.g., experienced higher increases in unemployment) in times of economic downturn. A Minorities Policy era investigation in 1988 identified that the majority of allochtonen live within the four largest cities within the Netherlands [56]. The high presence of allochtonen in urban environments and their low economic status focused the discussion about immigrant integration in the Netherlands to the city level. Programs at city levels were implemented throughout the 1990's to address socio-economic problems (with varying levels of success). These programs were not specifically directed towards immigrants but impacted them in practice because immigrants within Dutch cities were generally of lower socio-economic status [56]. These differences between autochtonen and allochtonen were the focus of many politicians.

Several Dutch politicians during the early 2000's assimilationist era believed that a society in which there were very little differences in the socio-economic outcomes between autochtonen and allochtonen was an integrated society [51], [56]. From 2002 onwards the Dutch government commissioned a biennial report on the status of immigrants within Dutch society. These reports had information on education and unemployment that Dutch politicians intended to use to remove immigrants from the disadvantageous position they held [56]. Since its inception the report has been produced by different Dutch agencies, and statistical categories have been added. In its current form, the report includes sections on population, refugees, education, labor, benefits, income, crime, health, and social and civic participation [57]. Researchers note that similarity between groups does not necessarily indicate the level of integration of individuals within Dutch society [51], [56]. However, comparing the status of groups is a method to examine whether or not disadvantages are present within the systems that constitute Dutch society. This thesis uses a method of comparative analysis between different ethnic groups to inform various model parameters. Differences between outcomes across groups and areas within a city are used to measure integration. The specification of the model is discussed in detail in the next chapter.

Summary

A combination of sociological research, urban modeling, and empirical data serves to significantly improve the understanding of the city as a system and the impact of refugees on the system, especially in the context of a specific city and region. The information herein and data from the CBS, and other sources, was used to specify, as accurately as possible, the city of Rotterdam, Netherlands in an urban dynamics model.

IV. Model Development

Overview

This chapter describes the Urban Dynamics Refugee Integration (UDRI) model developed in this thesis. First the model subsystems are described. The subsystems from the Sanders model [26] have been reorganized into three general subsystems: Land Use, Job Market, and Government. The subsequent sections detail the subsystems that have been added according the literature review: People, Legal, Education, and Social. Throughout each subsystem's description, system's mapping and quantitative modeling validation are shown. Following the Model Subsystems section are descriptions of validation of the entire UDRI model according to the framework established by Zagonel and Corbet [47]. In the final validation section two designed experiments are setup to test policy effects on integration measures.

Model Purpose

The purpose of a system dynamics model is three-fold. First, system dynamics models provide insight into the system being studied and the processes within them [48]. Second, system dynamics models replicate problematic behaviors of interest in the system [48]. Third, system dynamics models recommend solutions to the problematic behaviors using elements endogenous to the system [48]. A purpose of the Forrester urban model [45] was to replicate a city's growth, decline, and stagnation over many years. The initialized city area was small compared to its full land area (only 3000 acres occupied out of 100,000 total acres in the city area). Sanders and Sanders [26] explored the addition of internal movement to the same base city that Forrester used. This city was concentrated into two of sixteen zones. Both the Forrester and Sanders models demonstrate a city growing from infancy into full maturity; therefore, the time horizon in the Forrester urban model of 250 years is appropriate for their studies. The time horizon and model structure are set in a way to best investigate the issues with city growth and stagnation. The purpose of the UDRI model is different than the Sanders model and therefore requires some differences in specification.

This thesis proposes to examine and investigate changes to a city system with the introduction of new inhabitants, specifically refugees. The system behaviors of interest are a widening economic gap between ethnic groups and the redistribution of ethnic groups throughout the districts of the city. The problems that refugees face are immediate; they need to find employment and a place to live while completing their integration requirement. The impact of a quick shock to a labor market that is expanding (as in the Sanders model) is less than the impact of the same shock to a relatively stable labor market. The time horizon for a model that focuses on the effects that happen on people during an integration period and settling into a city is on the order of decades.

This study elects to use a time horizon of 30 years to examine the impact of refugee flow on a city. 30 years is enough time for individuals who arrive in the city to move through the integration system as well as other systems. Three decades is also enough time for a policy to be implemented to change economic outcomes for groups of people and for their children to be impacted by these policies in the education and job market systems. This time period is also short enough that it is relevant to policy makers. The political environment around the globe concerning refugees is currently very tense; politicians and city planners are seeking solutions that create a material positive impact in the integration and outcomes of refugees in a short amount of time. The current Dutch Integration System was implemented in 2007. Data used to conduct quantitative modeling validation was available through 2014. The UDRI model uses data during this time period to initialize the model in 2007 and then project into the future to the year 2044.

The shortened time horizon (relative to Sanders) and narrowed model focus has necessitated changes in the decision rules and model structure in various ways. The differences from the Sanders model and additions unique to the UDRI model are described in detail in the following Model Subsystems sections.

Model Subsystems

The following subsections are detailed explanations of each of the UDRI model's subsystems. Visualization of the UDRI model is used to help explain the flow and feedback loops throughout the model; however, some of the subsystems have upwards of 150 variables. For this reason, showing a visualization with every variable included is prohibitive. Additionally, including every variable of each subsystem is not necessary to understand the structure and flow of each subsystem. In the visualizations, variables from the Sanders model are in Times New Roman font, and information arrows are solid; variables that are unique to the UDRI model are bold, underlined and in Arial font, and information arrows added have dotted lines. The differentiation between components from the Sanders model and unique contributions in this study is important for the sake of clarity and defensibility of the UDRI model.

In this chapter when variables are mentioned by name (either full or partial) they are in written in italics. Some of the variables are descriptive in their naming, but many have initialisms for easy recognition (e.g. *BIDF Business industry density factor* is one complete variable name). This study uses Vensim PRO to model the city system, visualize the structure, and conduct experiments; Vensim code of the model is located in Appendix B.

Land Use.

The Land Use subsystem is a grouping of all of the variables that describes the physical layout of the city and the buildings that occupy the space. The city is a fixed area divided into the 14 districts (wijk) that comprise Rotterdam; the Sanders model had 16 zones of equal size arranged in a square. These districts were submunicipalities (deelgemeente), with their own councils that enacted municipal policy, until 2014 when the Rotterdam municipal government divested these submunicipalities of powers; the 14 districts in the city of Rotterdam maintained their boundaries, the title is the only difference. Each district is represented by an index *i* (called a subscript in Vensim and hereafter); Table 1 shows the mapping of district to subscript *i*. To describe distances between districts, a second subscript, *k*, is in the UDRI model as a destination subscript. Distances are defined as *D distance i k [i, k]* in a 14 x 14 array. Table 1 shows that the subscripts *i* and *k* are the same for each district.

The structures that occupy space within the UDRI model are *Business Establishments* and *Housing*. Each building structure is distinguished by the subscript *i* as well as a subscript that denotes a subcategory of building structure. *Business Establishments* are differentiated by the *class* of business: the activity that the business is grouped by according to the Dutch Standard Industrial Classification (SBI). The *class* subscript is described in detail in the Job Market section.

Table 1: District to Index Mapping

District	Subscript *i* (*k*)
Centrum	D1
Delfshaven	D2
Overschie	D3
Noord	D4
Hillegersberg-Schiebroek	D5
Kranlingen-Crooswijk	D6
Feijenoord	D7
Ijsselmonde	D8
Pernis	D9
Prins Alexander	D10
Charlois	D11
Hoogvliet	D12
Hoek van Holland	D13
Rozenburg[1]	D14

Housing is divided into three levels according to the three sectors of the Job Market: *High Income* (*HI*), *Middle Income* (*MI*), and *Low Income* (*LI*). Housing for each sector of the Job market changes based upon the construction of dwelling units and destruction or obsolescence (decline of housing into a lower income sector). *High Income Housing* ages and obsolesces over time and becomes *Middle Income Housing* which declines into *Low Income Housing* which is demolished at a fixed rate each year. Figure 4 is a visualization of this flow.

[1] Rozenburg was formerly a municipality, but decided to disband in 2008 to join Rotterdam [49]. It became a submunicipality of Rotterdam in 2010, so it has been included as a district in this analysis [49].

The subcategory of *Housing* is the *type* subscript (*single*, *multi*). Single family houses (eengezinswoningen) are denoted as those in which the housing unit is a standalone building. Multi-family houses (meergezinswoningen) are those in which housing units are combined in a building (e.g. flats, lower and upper dwellings, and so forth). The housing within the city of Rotterdam is fairly heterogeneous between districts. To capture these differences in housing distribution, the subscript *type* is used.

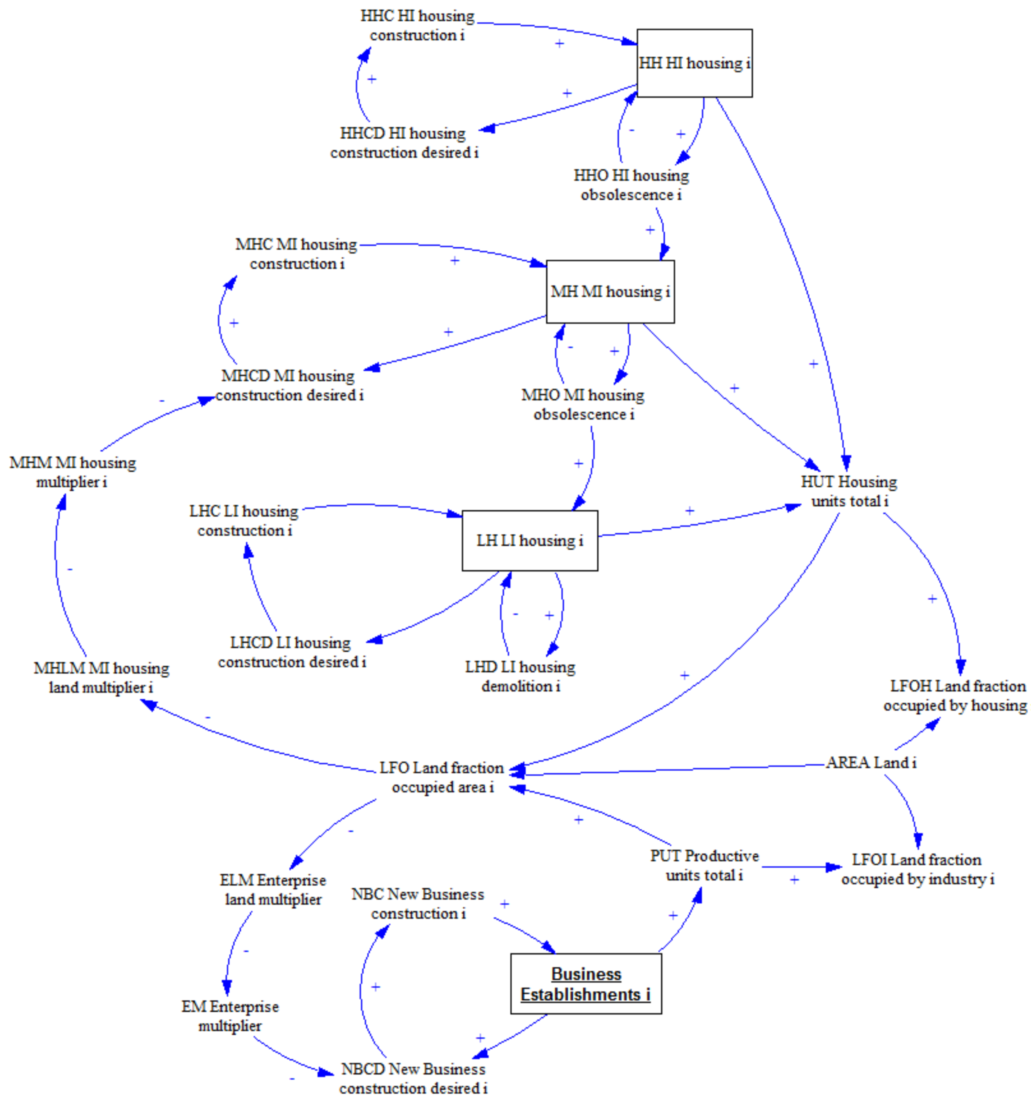

Figure 4: Land Use Subsystem

Construction of new buildings is determined by empirical constants that set the normal construction rate and multipliers that modulate the rate. An example of a multiplier is the housing land multiplier (e.g. *MHLM MI housing land multiplier i [i]*, shown in Figure 4) that uses the *LFO Land fraction occupied area i [i]*, in a lookup function. The *LFO Land fraction occupied area i [i]* is the ratio of land that is occupied by buildings (both *housing* and *business establishments*) over the land area in each district. A lookup function uses a variable as an input and returns a value according to a curve. Figure 5 shows the curve used for the *MHLM MI housing land multiplier i [i]* lookup function. This curve indicates that as the *Land fraction occupied area i [i]* increases, the *MHLM MI housing land multiplier i [i]* decreases; when *Land fraction occupied area i [i]* is 1, the housing multiplier is 0 and therefore no construction of *MH MI housing i[i]* occurs. The returned value is either the corresponding y-value (if it has been set) or the linear interpolation between the nearest neighboring points on the curve.

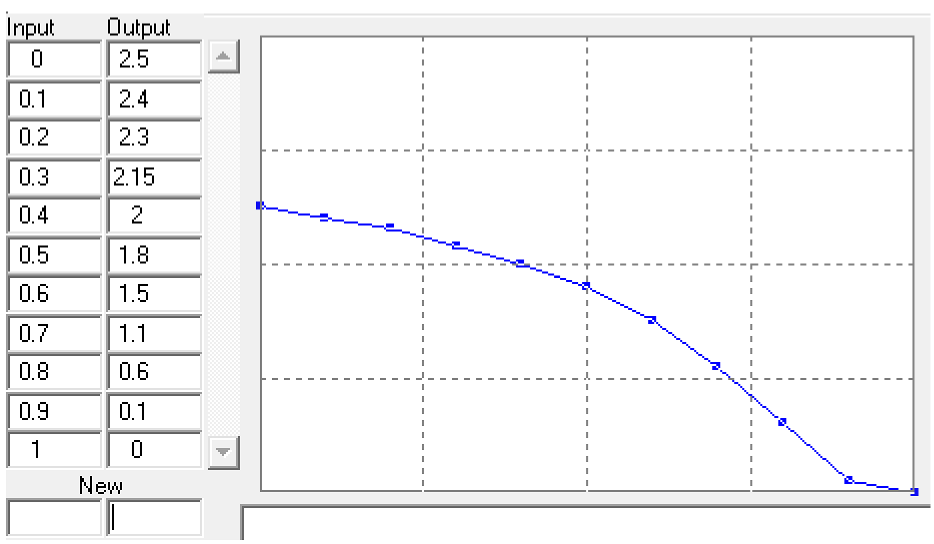

Figure 5: MHLM MI housing land multiplier i[i] lookup curve

Other multipliers that affect the rate of construction of housing include: *housing adequacy*, which compares the amount of people in each sector of income to the amount of housing units available in that district; *housing location attractiveness,* which increases according to the amount of jobs in the district; *housing growth*, which increase as the growth of that sectors housing increases. Construction of each sector of *housing* changes according to these multipliers.

The construction of *business establishments* is determined using similar types of multipliers that are used in *housing*. As the *Land fraction occupied area i [i]* increases the *ELM Enterprise land multiplier[i]* decreases, which decreases the *EM Enterprise multiplier[i]*, which decreases *NBCD New Business construction desired i[i]*. The variable *NBC New Business construction i[i]* is calculated using the number of *Business Establishments* in each class in the district, the *EM Enterprise multiplier[i]*, and *Businesses Opening Normal[class]* (net growth rate constant).

System's Mapping.

A large amount of system's mapping validation of Land Use has already been conducted by Sanders and Sanders [26], and before that, Forrester [45]. However, this study has changed some of the structure of this subsystem from the Sanders model.

In the Sanders model, *New Enterprise* units are built, and over time, transition into *Mature Business* units and then decay into *Declining Industry* units. Sanders maintained the assumption from Forrester's urban model that *New Enterprise* employs more persons in all income sectors than *Mature Business*, which employs more persons in all income sectors than *Declining Industry*. The differences in employment and flows between these industries is a major driver of city population growth. However, in the case of the UDRI model, the specific industries are represented. They have different net growth rates (businesses opening less businesses closing relative to industry size), and employ different amounts of people in each sector of the Job Market. This represents the same influence that the flow from *New Enterprise* to *Declining Industry* represents in the Sanders model; certain (generic) industries become more prominent while others become less relevant.

The face validity of the Land Use subsystem in the UDRI model was determined from an examination of the Dutch labor sector and Dutch housing market. There are different classes of business activities and different types of houses that exist in the Netherlands. Adding these subscripts does not violate the face validity of this subsystem, but it does call into question the level of aggregation. The level of aggregation is the granularity of the division of variables.

To determine whether or not the level of aggregation is appropriate for the structure of the model, there should be distinct differences between the divisions of the variable in terms of the impact of policy change. Changing the level of aggregation to include different *types* of *housing* is important for the sake of maintaining the approximate population density of heterogeneous districts. The different classes of the Job Market have different representations across the sectors of income as well as different ethnic groups. The differences in these variables indicate that using *class* and *type* are appropriate for the level of aggregation.

The decision rules within the Land Use system are very much the same as the Sanders model. The changes that were made were due to the decrease in time horizon. In the Forrester urban model (and in the Sanders model) an assumption is made that the city or regional attractiveness is not dependent on the amount of housing that is available. This is because over the long run, people will tend to move to a city because of job prospects and not consider the housing available; jobs are attractive and housing can always be built. In the UDRI model, people consider the attractiveness of a zone according to the amount of jobs in their sector available, the amount of housing available in their sector, as well as the economic and ethnic makeup of the city.

Quantitative Modeling.

The districts in the UDRI model are organized according to a rough mapping of Rotterdam. The distances between districts were determined using a combination of GIS and the approach that the Sanders model used. In Sanders model, the distance between districts was the straight-line distance from the center of an area to the center of another area. Each square in Sanders model was uniform, measuring 6250 acres, 3.125 miles by 3.125 miles [26]. The distance of each district to itself was half the side length. The distance to any other square was calculated using the Pythagorean equation.

To emulate the distance calculation used by Sanders, the UDRI model uses fixed geographical points as the center of each district. The fixed points were set using the geographic coordinates of each district in Google Maps. These coordinates represent the approximate geographic center of each district. The distance calculator tool native to Google Maps was used to find the pair-wise distance in kilometers between all districts. The coordinates used to identify each of the districts is in Appendix A. Calculations involving distance require a non-zero value for the distance from each zone to itself because distance is used as a denominator. In a similar approach to the Sanders model this thesis used half the length of the district square area. Equations (1)-(3) shows this calculation with the district D1 (Centrum). Each calculated distance of a district to itself was the smallest distance for each *i* and *k*.

$$AREA\ land\ [D1] = 438\ ha = 4.38\ km^2 \quad (1)$$

$$\sqrt{AREA\ land\ [D1]} \sim 2.093\ km \quad (2)$$

$$D\ distance\ i\ k\ [D1, D1] = \frac{2.093}{2} = 1.05\ km \quad (3)$$

The *LPP Land per production unit* (area of land for one business establishment) was determined by dividing the number of business establishments over the business and retail land area for each district and taking the average across all districts. A common value for all classes of business is not ideal because some classes of industry occupy more land area than others (e.g. agriculture vs. financial services).There was no more available information on land use for businesses that could be used to differentiate between classes of business so a common value had to be assumed. Of course, if more accurate data were available, this variable could be updated to re

To address disparities in the *type* of housing across districts, *LPH Land per house[type]* was calculated using the size of houses in the city of Rotterdam at large. Information was available at the district level about the number of housing units of each *type* [49]. The data indicated that each district had varying amounts of each *type* of housing. The district Centrum is comprised of 99% of multi-family housing units; 86% of Pernis housing units are single-family housing units. A housing unit is defined as the property in which a household (family unit or single individual) is living. This could be a standalone single building as one unit, or one multifamily unit out of many in an apartment building.

It was hypothesized that on average the size of single family housing units would be larger than multifamily housing units. Data of the amount of housing units in different bins of living space (measured in square meters) was available by *type* of house. Living space is defined by CBS as the amount of area in a housing unit that is suitable for living (i.e. floor space). The bins of living space ranged from the lowest bin of 2 – 15 square meters to the highest bin of 500 – 10,000 square meters. The *LPH Land per house[type]* was calculated with the sum product of the living area and the percent of houses that were in each bin out of the total amount of houses. To capture the difference between floor space and the actual land area foot print of a housing unit (i.e. a single family house may have 50 square meters of living space, but the building itself occupies more space) the high side of each bin was used in the sum product calculation. The estimated *LPH Land per house[single]* was 0.01 ha and the estimated *LPH Land per house[multi]* was 0.017 ha. The differences in land area may seem small between each *type* of housing, however, with thousands of housing units in each district, a common value would have created problems within the small, high density districts.

The initial values for *Business Establishments* and *Housing* were determined by a combination of data on the ratio of business classes and housing type and initial population calculations (shown in the Job Market subsystem section). This is important because the number of business units and housing units initial do not represent the actual amounts in Rotterdam. The population dynamic is the important aspect of the UDRI model's focus, therefore having the correct ratios of *business classes* and *housing types* is sufficient to capture the effect of these levels of aggregation. The calculation for initial *Business Establishments* and *Housing* is described in the Job Market.

Job Market.

The Job Market subsystem is a collection of variables that describe the employment in different sectors of the Job Market and movement of individuals throughout the city. There are three sectors in the Job Market: *Low Income*, *Middle Income*, and *High Income*. These three sectors are levels that have subscripts according to district (*i*, *k*), the ethnic group they belong to, and the class of activity they work in. Ethnic group is included in the UDRI model as the subscript *group* (*autochtonen*, *western allochtonen*, *nonwestern allochtonen*). Persons can move from *Low Income* to *Middle Income* (and vice versa), and from *Middle Income* to *High Income* (and vice versa). The class is based upon the Dutch Standard Industrial Classification (SBI), specifically SBI 2008 [49]. The *class* subscript has seven elements (*A*, *B-F*, *G+I*, *H+J*, *K-L*, *M-N*, *R-U*). Table 2 shows each subscript and the economic activities associated with it. This list is not all-inclusive of job types, these *classes* do not include government and other public service. These *classes* were chosen because there was data available on the number of firms of these types at the district level.

The amount of *Jobs* in each district change according to the amount of *Industry* and that is present. *Industry Jobs* are divided into *HI*, *MI*, and *LI* with different amounts of personnel required for *New Enterprise*, *Mature Business*, and *Declining Industry*.

The rates at which people move between sectors of the Job Market are affected by conditions of the Job Market in each district and in the city at large. People move between districts, arrive to the city, and leave the city at standard rates. Figure 6 shows this flow.

Table 2: SBI 2008 Classifications by Activities

SBI 2008 (class)	Activities
A	agriculture, forestry and fishing
B-F	industry, energy, and construction
G+I	trade, hotels, and restaurants
H+J	transportation, information, and communication
K-L	financial services, real estate
M-N	business services
R-U	culture, recreation, and other services

The flow rates are modulated by the attractiveness of each zone as compared to the city average attractiveness. *Attractiveness* of each zone is calculated separately for each sector of the Job Market. For example, *Attractiveness* to Middle Income people for each district is calculated by the amount of MI jobs available, the amount of MI housing, and the ratio of MI people in each area.

The rate at which people arrive into the city system is a combination of normal inter-municipal movement rates (multiplied by job availability multipliers), the refugee arrival rate and immigrant arrival rates. The values for these rates are in the People subsystem.

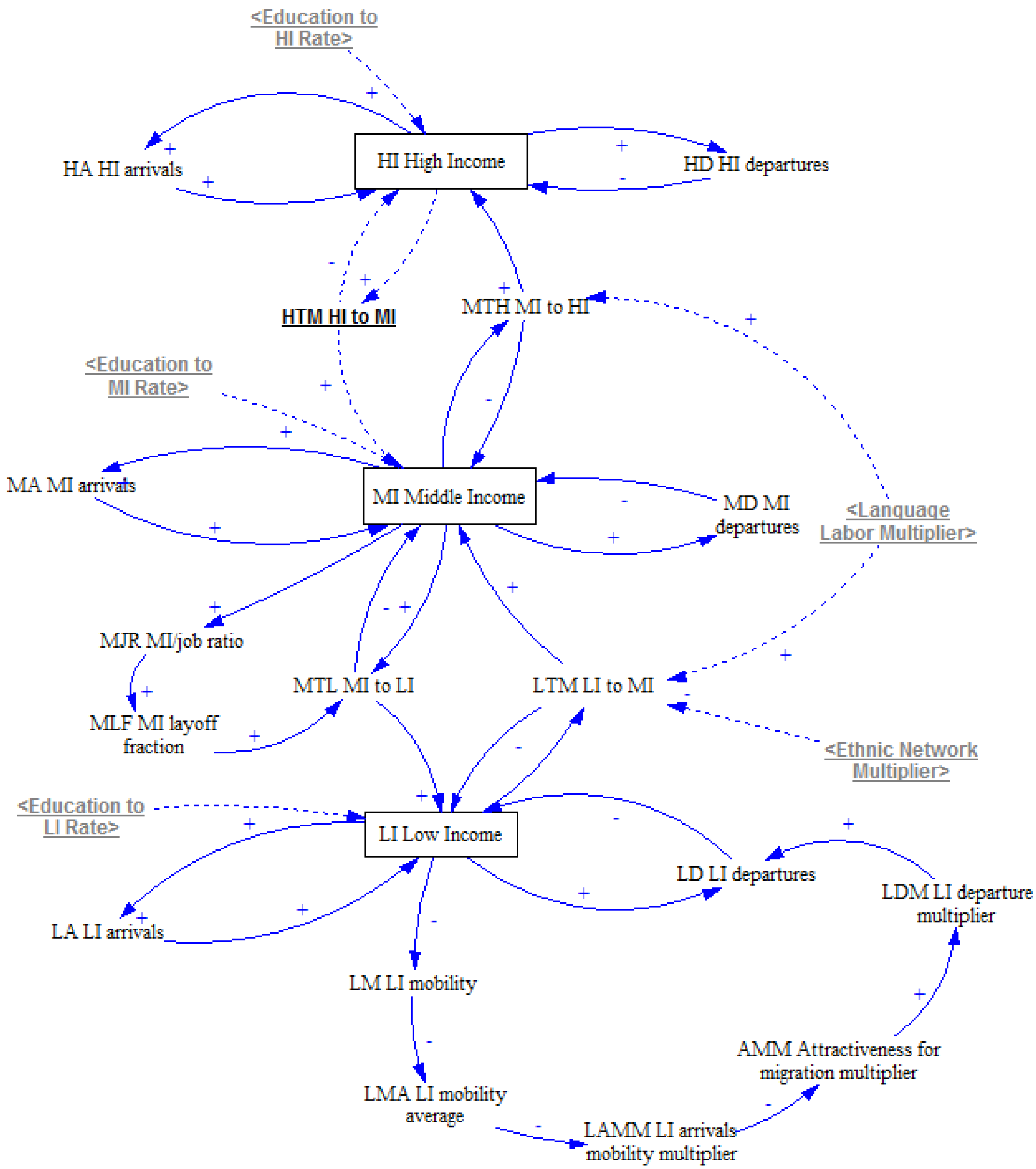

Figure 6: Job Market Subsystem

System's Mapping.

This Job Market subsystem makes two assumptions that limit the validity of this subsystem's mapping. The first assumption is that persons live in the same district in which they work. This assumption is a holdover from the Sanders model in which persons would move to growing parts of the city as industry and housing was built. In a modern city, especially a relatively small one such as Rotterdam, people may live in one area and commute to another for work. This is especially true of persons of lower economic status who might work in a certain area but cannot afford to live in the area. This study holds to the same no-commuting assumption used by Sanders. The reason for maintaining that assumption is that the decision rules and structure for the Sanders model have been validated previously. This study has used Sanders as a framework to specify a city and added the subsystems and influences relevant to refugee integration. Changing the decision rules to include commuting would render much of the rest of the model invalid because all of the pieces operate under the no-commuting decision making scheme. If the proper information were available, however, this assumption could be relaxed and the changes incorporated in an updated version of the model.

The second assumption is that persons do not transfer across classes of the Job Market during the duration of the time interval modeled. According to the decision rules in the UDRI model, the population of persons who are in a particular class cannot transfer to another class of the Job Market, even if it is more attractive than their current class. The impact of a labor shock causes changes within each class in varying ways. When a labor shock hits a market, the short-term reaction may include persons who obtain training and begin working in a different class of business. The number of persons who are able to change job class to adjust to labor shocks is assumed in the in this initial model to be insignificant compared to the dynamics between districts, sectors of income, and ethnic groups studied within the UDRI model. Although this movement does occur in reality, it is postulated that it does not add significant value to the insights for the study of refugee integration and is therefore not included.

This study has changed the names of the Job Market sectors from Underemployed, Labor, Managerial-Professional to Low Income, Middle Income, High Income, respectively. This change reflects the updated language that is used to refer to these groups. For example, low income is a better description of the sector of the Job Market with low paying jobs and low skill. The denotation of Underemployed implies that individuals in that sector have higher skill levels than those that are required for the job in that they are working. Although this may be true for some individuals, the Underemployed sector in the Sanders model functioned in the same way that the low-income sector functions in modern society; therefore, the naming changes were made to better describe the sectors in the Job Market.

The *Accessibility Attractiveness* of zones was preciously calculated without consideration for the amount of jobs that were available to members of different sectors. That is, in the Sanders model a zone that has more MI jobs is more attractive than one that has fewer, irrespective of the amount of MI persons who are already in that zone. *Accessibility Attractiveness* is a driving factor for movement of persons in between districts. If a zone has more jobs than the one the person is currently living in (relative to the distance between zones) then the rate of movement increases to the zone with more jobs. The UDRI model divides the number of jobs in each class by the amount of people in that sector of income to calculate *Accessibility Attractiveness*.

Including *class* as a factor for the decision rule of movement within a city is appropriate level of aggregation. This is because there may be many available jobs in a district for a certain *class* but not another; therefore, that zone should look attractive to all persons in the appropriate sector of income and class and not to those of a different class. The class aggregation is also valid in the context of education and the types of careers that person enter once they finish school. The impact of the class dynamic is discussed further in the Education subsystem section.

Quantitative Modeling.

The initial values for *HI High Income, MI Middle Income*, and *LI Low Income* (discretized by *i, group,* and *class*) are from a combination of various CBS data sources. CBS open data at the district level was collected on the number of persons in each sector of the Job Market, the population of each district, the ethnicity ratios, as well as the number of businesses in each *class*. The data about these different distinctions between persons was not in a combined format. For example, there is data available on the percentage of *high income* persons in a district and the percentage of *allochtonen* within a district; however, there is no data available on the percentage of *high income* persons who are also *allochtonen* in each district. For this reason, the initial values of *HI High Income* and other sectors of the Job Market were assumed to have equal representation according to the ethnic *groups* and *class*.

For example, in Hoogvliet the population in 2007 (excluding those 15 and under, and adults in education) was approximately 27,893 persons. In that district, 13% of the population were in the *high income* category (CBS definition is persons with the top 20% of disposable income, greater than 41,500 euros annually), and 23% of the population was *non-western allochtonen*. The initial *HI High Income*, *non-western allochtonen* persons was set at 834 persons. This is the district population multiplied by the percentage of *high income* persons and multiplied by the percentage of *non-western allochtonen*.

Although the calculation of initial population in each sector of income assumed equal representation, there were still disparities in the overall distribution of ethnic groups. Table 3 shows the proportion of population for each sector of income by group. The first column of ratios shows the actual 2007 proportions in the city of Rotterdam. The group columns show the initial proportions that were calculated. The difference between groups indicates that there is a higher proportion of persons with *low income* in neighborhoods with higher proportion of *allochtonen*. This is a result that has been indicated by numerous studies on economic outcomes of immigrants in the Netherlands and elsewhere [51], [58]. The difference between groups across the sectors of income may very well be greater, but there was not enough data available for this research to support a different method of initialization. The initial populations in each in sector of income by group may not perfectly match the actual 2007 Rotterdam values, but the disparity is sufficient to initialize the model.

The assumption of equal representation in groups is held except for the *refugees*, who were assumed to initially have no *HI High Income* persons. The proposed initial *refugee HI High Income* population (according the proportions shown in Table 3) was added to the *LI Low Income* sectors. This assumption falls in line with the literature about refugee economic outcomes [15], [16], [18].

Table 3: Initial proportion of sectors of income by group

	Rotterdam 2007	autochtonen	western allochtonen	non-western allochtonen
High Income	0.14	0.145	0.136	0.110
Middle Income	0.33	0.342	0.333	0.323
Low Income	0.54	0.513	0.531	0.566

To determine the amount of initial *housing* in each district, the population of each sector of income (including the population under 15 and the education population) was multiplied by the inverse of the ratio of empty houses by district, and the ratio of housing type by district. The actual number of housing units needed to accurately initialize housing is found by dividing the population of each sector by the average household size of Rotterdam (2 persons). A housing unit is one that a household lives in; this could be a single person living on their own, or a family with children. The actual family dynamics do not matter as long as the amount of housing accommodates the average of two persons living in each housing unit throughout Rotterdam.

To find the number initial *businesses*, the number of persons working in each firm (number of jobs) had to first be determined. The average number of employees per firm in each class was calculated using a process similar to the calculation for house size. Data from the CBS on the number of firms by amount of working persons was available at the national level. The average persons per class was found by calculating the sum product of the number of employees in each company (higher value of the range) and the proportion of firms of that size. In many sectors the distribution of company size was skewed towards the low end with the majority of companies in a class being single person companies (i.e. entrepreneurs, self-employed persons). The number of initial *businesses* was modeled as dependent on the average number of persons working in each sector because the population of each district had been established and data of the ratio of business by class was available at the district level. A low estimate of employees per company would give an amount of businesses that would not fit in the land area per district. This study elected to exclude single persons from the calculation of average persons in each *business* to maintain laws of conservation in the model. Table 4 shows the calculated number of jobs per class of business as well as the number of jobs per class of business by sector of income. The average city wide distribution of sectors of income was used to divide the jobs accordingly and maintain a common number of jobs per firm across all districts.

Table 4: Jobs per class by sector of income

Class	Total jobs	High Income Jobs	Middle Income Jobs	Low Income Jobs
A	5.3	0.7	1.9	2.7
B-F	21.9	3.2	7.8	10.0
G+I	11.9	1.7	4.2	5.9
H+J	18.4	2.7	6.5	9.2
K-L	10.3	1.5	3.6	5.1
M-N	15.9	2.3	5.6	8.0
R-U	10.8	1.6	3.8	5.4

The initial number of business establishments was set by multiplying 2007 values of businesses in each district by a scaling factor (while maintaining the ratio of business classes in each district) until the total district working population had employment of 95% to match the 2007 national unemployment rate of 5% [49]. Using the 2007 ratio of business classes maintained the distributions of economic activities throughout the city of Rotterdam, while the scaling factor adjusted the number of business establishments to accommodate the number of people in each district. The non-commuting assumption means that persons were initially overrepresented or underrepresented in some districts in classes of businesses. For example, in the district of Hillegersberg-Schiebroek the proportion of high income persons is 0.28, the highest of any district in Rotterdam. The number of jobs per class is calculated using the city-wide average ratios firms per sector. The agriculture industry ratio of 0.056 puts 11 persons of the high income sector into that class while the ratio of agriculture, forestry, and fishing firms in Hillegersberg-Schiebroek of 0.00357 supplies 6.4 high income jobs. This sets the initial high income to job ratio in Hillegersberg-Schiebroek for agriculture, forestry, and fishing at 1.7. There are other instances where the job ratio is as low as 0.5. This is the result of the non-commuting assumption and the assumption that persons are equally represented in each industry according to jobs per class.

The impact of this initialization is an initial drop in the UDRI model working population of the city as some persons leave undesirable areas and move to more desirable areas. After a short break-in period, the model city population begins to grow at a rate similar to one that is seen in Rotterdam [49]. Figure 7 shows the population of the city over the first seven years of the simulation.

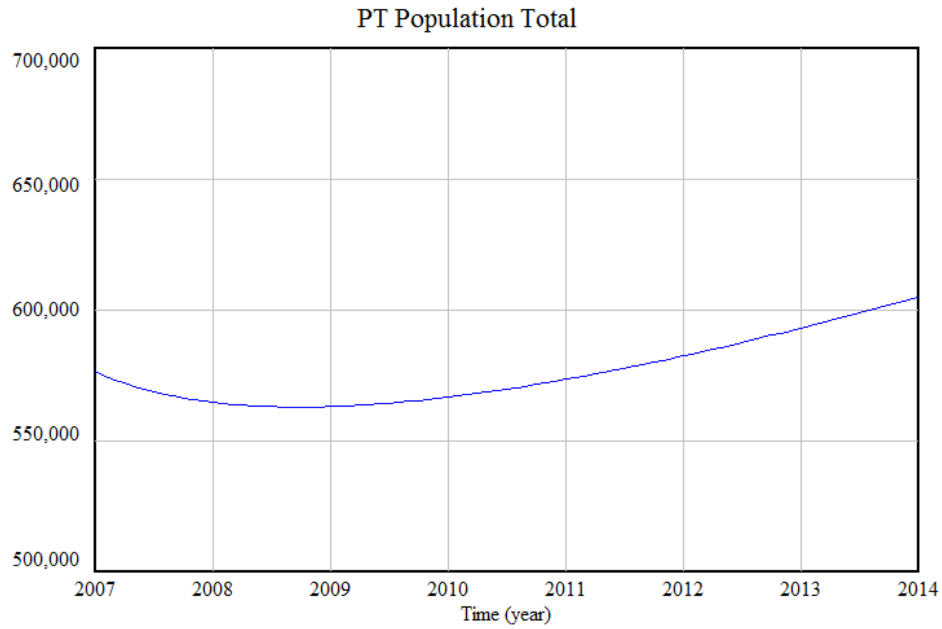

Figure 7: Population Total '07-'14

Government.

The Government subsystem is a combination of the *tax system* and all of the *programs* that are included in the UDRI model as policy decisions. This subsystem is not as interconnected within itself as the other subsystems are. The variables under control of the government are connected to the other subsystems in ways that enable policy makers to affect the UDRI model system as a whole. Policy decisions in the Government subsystem include: *housing construction programs*, *jobs programs*, *training programs,* and *language programs*. The tax structure includes the assessed taxes for businesses, housing taxes, and income taxes.

System's Mapping.

Gathering the *programs* and *taxes* into one subsystem was done to separate the parts of the UDRI model that are under the control of the government from the autonomous variables that interact according to the specified decision rules. Each *program* uses the subscript *i*; some of the *programs* add the subscript *group* for policy that can vary across ethnic groups. This system has face validity because the programs that are included are those that are potentially controllable factors.

The UDRI model does not represent the mechanisms by which the government would approach the implementation of each program. The program rates are results (e.g. jobs, houses) that are added to the appropriate level variables in addition to the normal amounts that change according to the autonomous processes in each subsystem.

Quantitative Modeling.

The three-tiered Job Market fits well with the progressive tax system in the Netherlands. Taxes are assessed at a higher rate for those in higher income groups. The taxes assessed for a person in each sector of the economy was found by using the CBS defined cutoffs for earnings in each of the sectors and Organization for Economic Co-operation and Development (OECD) tax rates for the Netherlands [59]. The tax revenue per person averaged over seven years (2007 to 2014) is used in the UDRI model to provide the *taxes assessed* for persons from each sector of the Job Market. The OECD also provided the tax per capita at the Dutch national level [59].

There was no publicly available data on the business taxes assessed per firm in each class of activity. For this reason the tax revenue from each business firm was set at the same value of 300 thousand euros per firm. This value is the same that is used by Sanders for New Enterprise (in Sanders it was 300 thousand dollars). If more information were available about the business taxes assessed per firm, this variable could be updated.

CBS data was available for the average house value for the city of Rotterdam. The values were not available by housing type or by sector of income. The ratios of housing assessed values for each sector were maintained according to the Sanders model and were multiplied by 5% of average house value of Rotterdam.

These numerical values themselves do not necessarily represent the actual taxes in the city of Rotterdam. The tax multipliers that are used in this study are influenced by the ratio persons in sectors of income. For the purposes of the UDRI model, the relative tax amounts between sectors is the most important aspect.

People.

The People subsystem is a collection of all of the variables that pertain to people within the system. The variables in the People subsystem include *working population, education population* and *births*. These variables are those that regulate the natural population growth of the city. As the population increases the births increases, people flow into the birthed children variable, which in turn flow into the education system.

Other variables in the People subsystem include *family size*, *birth rate*, *youth arrival rate*, as well as immigrant arrival rates and job sector ratios. *Youth arrival rate* is a variable that is used to separate the persons who are under the age of 18 (thus under compulsory education laws) into the Education subsystem. Figure 8 shows the organization of some of the variables in the People subsystem.

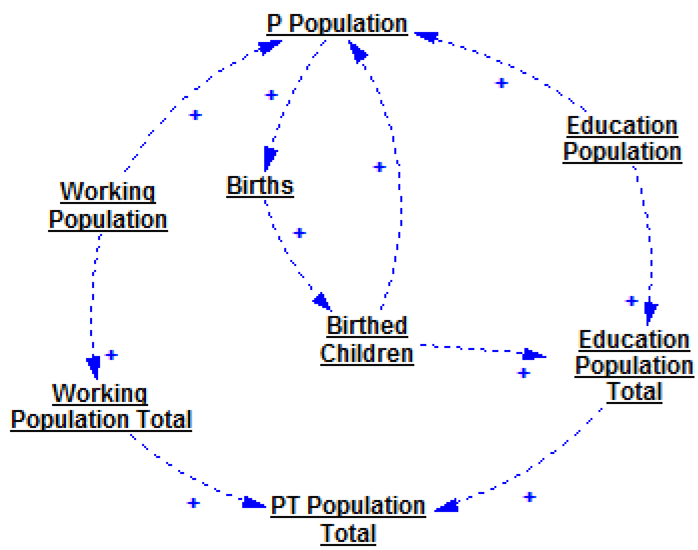

Figure 8: People Subsystem

System's Mapping.

The People subsystem has face validity because it is a simple flow of the populations of persons. This subsystem is similar to other population models in the way that the increase in population positively affects the birth rate. The UDRI model separates people into a working and education population because it is assumed that persons who are in the education system do not make decisions about where they will move. This is because the majority of persons who are in the education system are under the age of 18 and would be assumed to be living with parents or guardians. Persons over the age of 18 in the education system are not necessarily influenced by the Job Market in their district.

Quantitative Modeling.

The birth rate was determined using the Rotterdam net birth ratio (births per 1000 people less deaths per 1000 people). It was hypothesized that the birth rates were not the same among ethnic groups. Rotterdam has a higher ratio of *allochtonen* and a higher birth rate than their respective national averages. To determine whether or not there was a difference in birth rates among groups the national ratios of ethnic groups was compared to the national births by ethnic groups. Table 5 shows the average ratio of ethnic groups and the average ratio of births by ethnic group over the years 2007 to 2014.

Table 5: Population and birth ratio by ethnic group

	autochtonen	western allochtonen	non-western allochtonen
Ratio of population	0.795	0.092	0.114
Ratio of births	0.718	0.099	0.182

These results show that allochtonen persons account for a higher percentage of births than their percentage in society. The ratio of the population and birth ratios were multiplied by the Rotterdam net birth rate to set the birth rate constant for each group.

The immigration ratio (persons arriving from a different country per 1000 people) was available for the city of Rotterdam. The refugee arrival rate into the city of Rotterdam was not available. As a replacement for this, the asylum requests at the national level were used. Asylum requests by persons of each group were divided by the national group populations to find a ratio of asylum requests per person in each group. This ratio was multiplied by the initial group populations of the UDRI model to estimate the refugee arrival rate in numbers of people per year. The rate of refugee arrival was not set as a rate that is dependent on the group populations because that is not necessarily how refugee movement works. The asylum requests per year is not dependent on internal conditions of Rotterdam or the Netherlands, but more dependent on external conditions that create refugees (e.g. war, or armed conflict).

Legal.

The Legal subsystem is a representation of the Dutch integration program. The subsystem includes variables for *new migrants* (both *refugees* and *immigrants*) arriving to the city, as well as the levels for people who are in the integration period and in various stages of the integration system. People enter and transition to one of three places: *integration exam*, *NT2*, or *exempt*. From there, persons proceed into the naturalization process or permanent residency. People who do not pass the exam retake the test and a small proportion exit the city system. Figure 9 shows the structure of the Legal subsystem.

Refugees are the amount of people who have entered the city after being granted asylum from the government of the Netherlands and their children. *Immigrants* are those who migrate from other countries into the Netherlands and then subsequently enter the city. These are different from persons who are of the same ethnic *group* but are already Dutch *citizens*. This is an important distinction because the persons of each *group* who migrate in and out of the city freely according to housing and economic indicators are Dutch *citizens*. The *immigrants* from each *group* may exit the city through the Legal subsystem; these arrivals and exits (by *i* and *group*) are still tracked within the People subsystem.

This subsystem is a parallel structure to the People, Job Market, and Land Use. This is because the levels of the amount of people arriving into the Legal system (according to subscripts *i* and *group*) is equivalent to the amount of *immigrants* and *refugees* entering the city (also according to subscripts *i* and *group*). The only exception to this is the *autochtonen group*; persons whose parents are both of Dutch origin are not considered to be *immigrants*, even if they are entering the city system. Accordingly, the *autochtonen group* is not tracked within the Legal subsystem. The amount of people in each exam variable, the *permanent residents*, and *citizens* are maintained at the appropriate district level according to the movement within the Job Market subsystem.

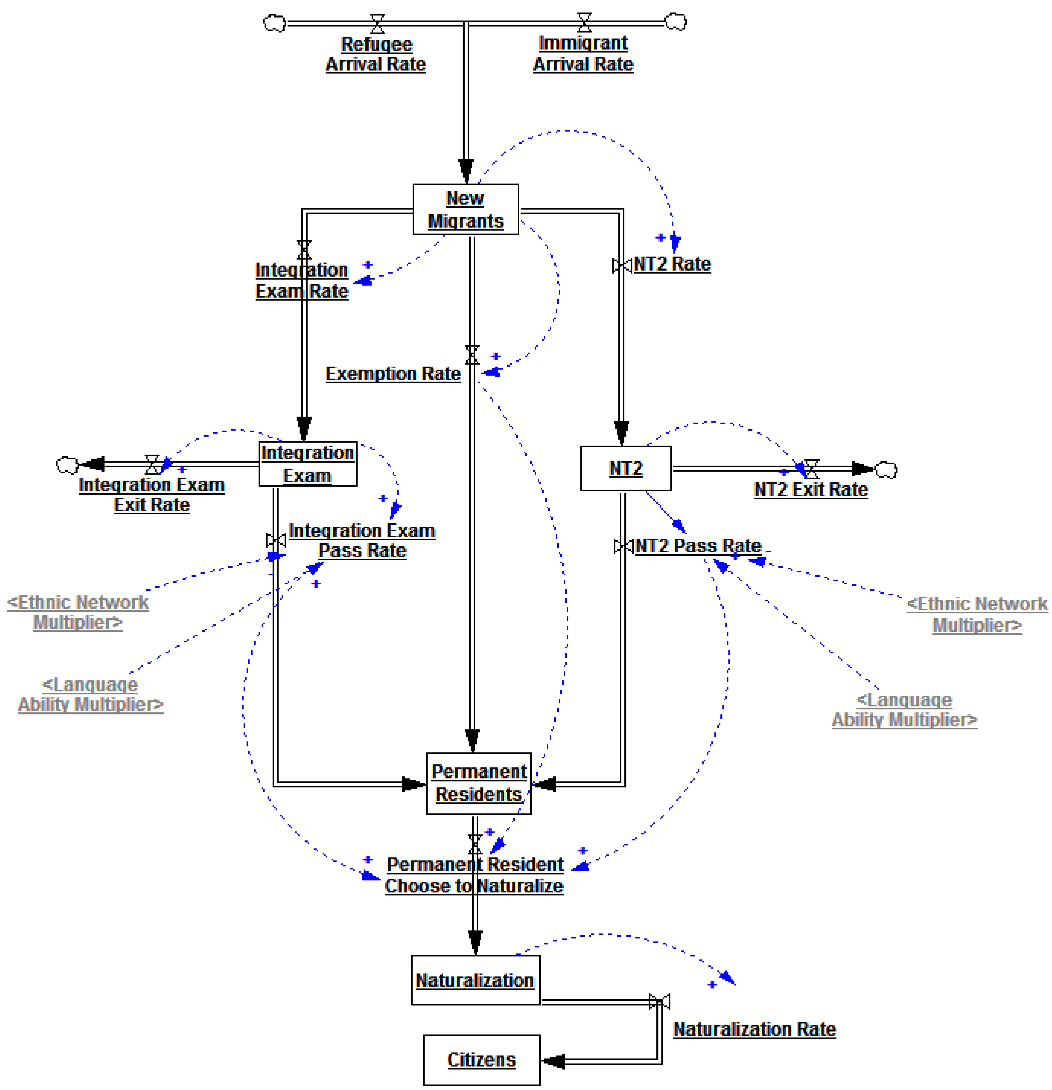

Figure 9: Legal Subsystem

System's Mapping.

This system structure was developed using information from the Dutch Immigration and Naturalization Service (IND) websites [33], [34]. According to Dutch integration policy in effect at this time, all newly-arrived immigrants are subject to the completion of either the Civic Integration Exam or the NT2, or they must be exempt from taking it according to specific criteria. Exemption criteria includes those who have a degree from a school that was taught in Dutch language and illiterate persons. Once persons become permanent residents they have the option to choose to naturalize and become a citizen.

Quantitative Modeling.

The NT2 is an exam that is taken by individuals who seek to pursue higher education or obtain employment certifications in a higher-skill career field. The rate that people elect to take the NT2 is set as the group rate constant for individuals entering higher education; the two rates are the same because the type of people who take the NT2 and enter higher education have the same intentions so the higher education rate was used to set the NT2 rate. Information of the success rate for individuals taking the exam was found in reports on the NT2 exam from the Dutch Ministry of Education, Culture, and Science (OCW) [60], [61]. The reported 2007 overall passing rate of 61.5% was used as the NT2 Pass Rate constant.

There was no public information available about the rate that people elect to take the Civic Integration Exam or the rate that people who take the exam pass it. The NT2 requires a more advanced mastery of the Dutch language than the Civic Integration exam. This might mean that the passing rate for the Civic Integration Exam would be higher than that of the NT2. However, persons who are taking the NT2 are likely more skilled in the Dutch language than those who elect to take the Civic Integration Exam. It is for this reason that the Civic Integration Exam passing rate constant was set as the same value as the NT2 passing rate constant. The rate that people take the Civic Integration Exam is equivalent to the rate that persons choose to attend vocational schools; the NT2 rate and Civic Integration Exam rate comprise almost all of the proportion of people entering the Legal subsystem. The remaining people (approximately 1%) is the rate that people are exempt from taking either exam.

The rate that persons choose to naturalize was determined from CBS national level data on the number of naturalizations per immigrant. The rate is assumed to be a constant 2.9% of persons who pass each exam (or are exempt). The rate that persons are denied a residency permit after failing to complete the integration requirements is not publically available. This rate was assumed to be minimal so each test was assigned an exit rate of 0.5% of persons leaving per time period.

Education.

The Education subsystem is a representation of the school system in the Netherlands. The Netherlands education system is administered by the Dutch Ministry of Education, Culture, and Science (OCW). Youth in the Netherlands generally enter education at the age of 4 [62]. Then, the majority of student progress through mainstream *primary education* (BAO) which lasts 8 years; a small proportion of students attend special education (SO) or special primary education (SBAO) during this time period [62]. Students who attended special education (SO) or special primary education (SBAO) proceed to elementary vocational training (*PRO*) or secondary special education (*VSO*) [62]. Figure 10 illustrates this flow as it exists in the UDRI model.

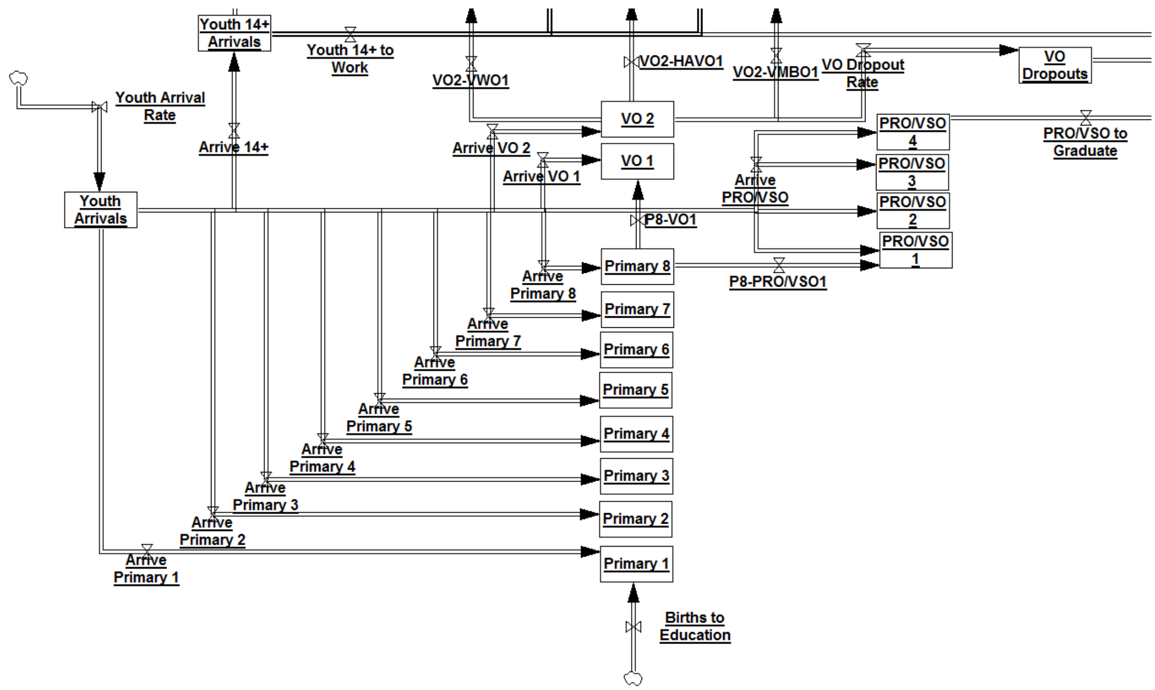

Figure 10: Primary education and transitional secondary education

At the end of primary education (BAO) students take a test (known as Citotest or Cito-toets) that recommends the route they should take in secondary education (*VO*) [62]. Secondary education (*VO*) lasts two years and helps student transition into their particular focus-area; students can either select to focus on academic or vocational education. Students entering pre-vocational secondary education (*VMBO*) are those who prefer (or were recommended) to learn skills and knowledge as they apply to a particular vocation [62]; pre-vocational secondary education lasts for two years. Academic secondary education is divided into two tracks: pre-university education (*VWO*) and general secondary education (*HAVO*) [62]. These tracks are tailored towards the two different types of tertiary education. Pre-university education (*VWO*) lasts four years and is intended to prepare students for academic higher education (*WO*); academic higher education (*WO*) institutions are universities that focus on research and theoretical application of knowledge [62]. General secondary education (*HAVO*) lasts for three years and is expected to prepare students for professional higher education (*HBO*): education that is more focused on practical applications of knowledge in a particular field [62]. Students can transfer between different programs during their secondary education depending on qualification and availability [62]. Figure 11 shows the levels of secondary education as they are represented in the UDRI model.

Beyond pre-vocational secondary education (*VMBO*) there are four levels of vocational education (*MBO*) [62]. The four levels of vocational education (*MBO*) are denoted by numbers (e.g. *MBO 2*). Each level lasts a different length and teaches different types of vocational skills. *MBO 1* is focused on simple executive tasks; *MBO 4* teach middle-management skills and graduates have the ability to enter professional higher education (*HBO*) should they choose to.

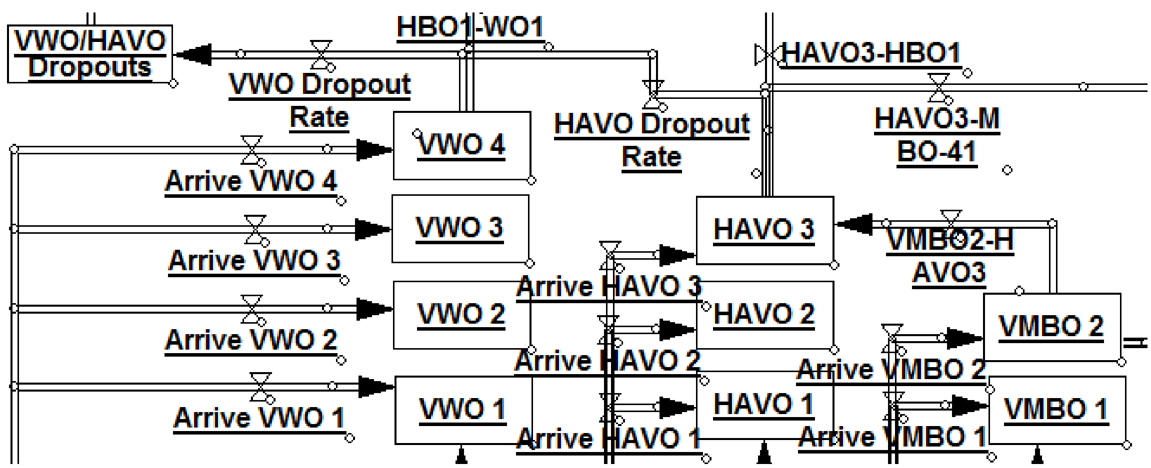

Figure 11: Secondary education

System's Mapping.

The Education subsystem structure is developed directly from OCW [62]–[64] and OECD [65] reports. These reports describe the flow of students between levels of the education system as well as average dropout and graduation rates. The representation of Dutch education in the UDRI model is accurate for the time horizon of this study; all of the OCW reports [62]–[64] show the same school structure and there have been no changes made to the system structure since the publication of the most recent (2013) report found. Each level of education includes the subscripts *i* and *group*. The structure of the Education subsystem is intuitively linked to the Job Market; for example, individuals who dropout of education before they have basic qualifications (according to OCW) will enter the *Low Income* sector. Figure 12 shows the full Education subsystem to provide perspective on the flow between the previously shown Education figures.

As persons move throughout the city, a proportional amount of persons in the same ethnic group move with them. The persons in the education system that move are those who are under the age of 18. This education system assumes that persons in secondary education or lower are those who live with parents or guardians and therefore move in proportion to movements in the Job Market.

This education system assumes that students flow through each level with dropouts occurring in the last year of each level (before students move on to the next level). This is because there was data available on dropout rates from each level of education, but not on the year that people drop out. The UDRI model makes the optimistic assumption that each student is given the best opportunity to succeed at each level before they dropout.

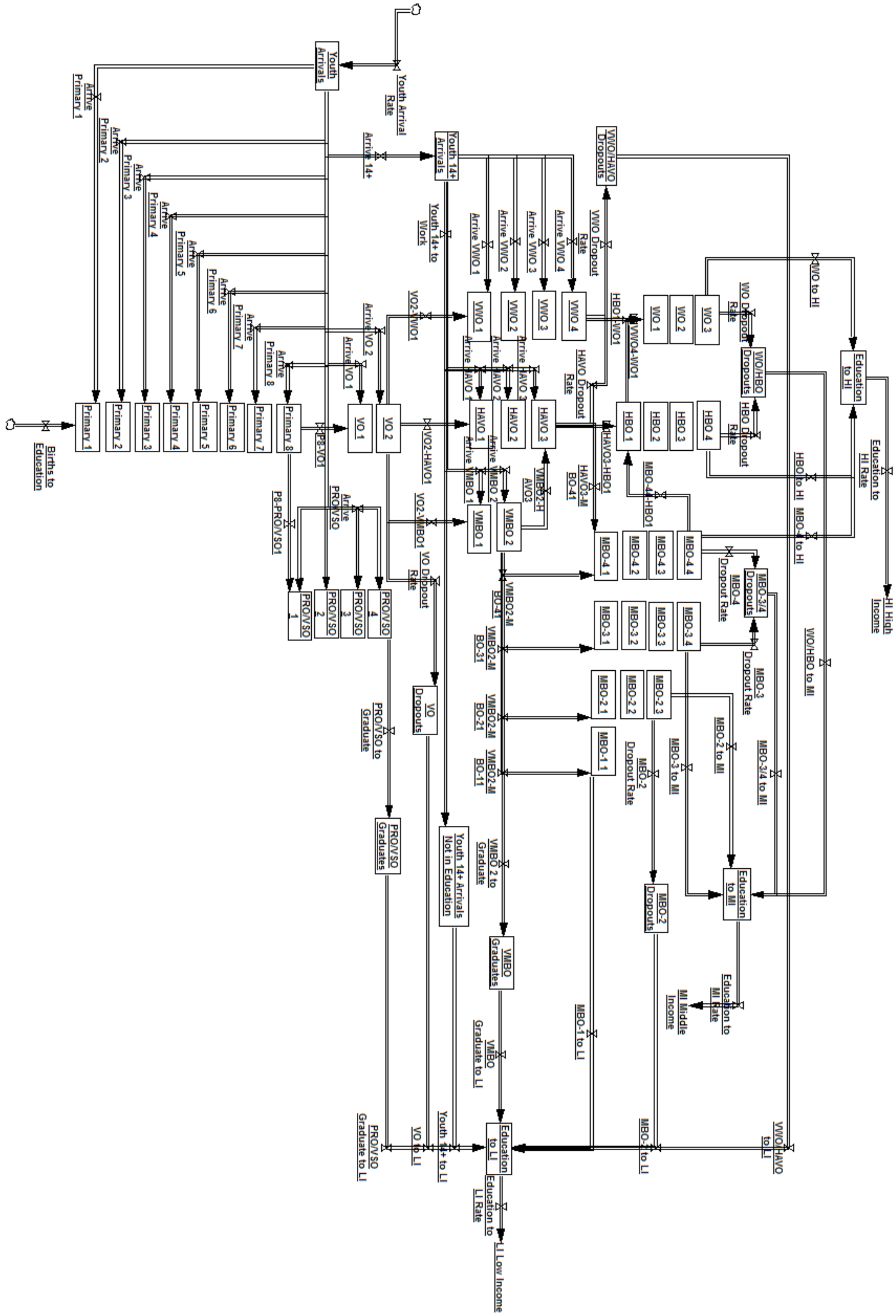

Figure 12: Education subsystem

Quantitative Modeling.

This subsystem was quantitatively validated in isolation prior to connecting it to the other subsystems in the UDRI model. This quantitative validation was done by using a constant population of 100 students entering the system. A constant inflow of students allowed for direct comparison to outflow; determining the percentage (number of persons per 100) of qualified and unqualified students exiting the system from each year group that entered would not be possible with an increasing population. Rate constants for transition between education levels were set according to the OCW report [62, Fig. 2.1]. These numbers are averages across the Netherlands education system. Identical outflows of percentage of students from each of the levels of education confirmed that the education system was quantitatively valid.

The rates for dropouts, choices of education track (between academic and vocational), and the subjects of study were different among ethnic groups. Non-western *allochtonen* had actual dropout rates two times greater than their *autochtonen* classmates. *Non-western allochtonen* were much less likely to enter academic secondary education (*HAVO/VWO*) and chose to enter vocational secondary education (*VMBO*). To model this, the rates between levels of education and dropout rates were set at the average value for *autochtonen* students. The rate for selection of either academic or vocational education were multiplied by economic integration of low income persons for each group of *allochtonen*. The economic integration is a variable that is explained in the Social subsystem section.

Social.

The variables in the Social subsystem are created from literature that describes social phenomena An example is Benenson's [40] *economic tension*, which influences people's residential decisions through comparison of a person's economic status to that of their neighbors. Other variables in the Social subsystem that have been adapted from literature include *cognitive dissonance* [40] and *ethnic network multiplier* [15], [20].

Another major function of the Social subsystem is to provide measures of integration for *refugees* and *immigrants*. Integration is measured by three variables: *economic integration*, *legal integration*, and *social integration*. Each of those integration variables is comprised of variables that address different components of each aspect of integration. The variables compare the economic, legal, and social status of each *allochtonen group* to the *autochtonen group*. The aim of the current Dutch integration system is to minimize the differences between immigrants and the native Dutch population. For this reason, the integration measures in the UDRI model are ratios of variables for each group over the same variables for *autochtonen*. An example of this is the Economic integration of low income persons. The fraction of low income persons in each group population is divided by the fraction of low income persons in the *autochtonen* group population. A value greater than one indicates that, relative to their *group* populations, a *group* has more persons of *low income* status; it follows that an integration variable value less than one indicates that a *group* population has relatively fewer persons of that designation. Table 6 shows the integration measures used in the UDRI model. It should be noted that the value of each of these measures is one for the *autochtonen group* because they are they baseline to which other *groups* are compared to.

These measures are used as response variables in the policy experiments conducted in the forecasting/optimization validation section.

Table 6: Integration measures

Variable Name	Formula
Social Integration Total	$\frac{Dutch\ Speakers}{PGT\ Population\ Group\ Total}$
Legal Integration Total	$\frac{Permanent\ Residents + Naturalization + Citizens}{PGT\ Population\ Group\ Total}$
Economic Integration Low Income	$\frac{Fraction\ LI\ of\ Group\ Working\ Population\ [group]}{Fraction\ LI\ of\ Group\ Working\ Population\ [autochtonen]}$
Economic Integration Middle Income	$\frac{Fraction\ MI\ of\ Group\ Working\ Population\ [group]}{Fraction\ MI\ of\ Group\ Working\ Population\ [autochtonen]}$
Economic Integration High Income	$\frac{Fraction\ HI\ of\ Group\ Working\ Population\ [group]}{Fraction\ HI\ of\ Group\ Working\ Population\ [autochtonen]}$

Similarity is used to measure integration because of the Dutch integration policy focus, but also because of the social impacts of differences between populations. Refugees who are markedly different from the majority in terms of culture, ethnicity, and lower economic status are more ‘visible’ to native persons in their host nation [11], [35]. High visibility (i.e. visibly different) refugees are likely to reinforce public perception of asylum seekers being a burden on society: whether or not this is the actual truth [11]. Refugees who are not able to achieve equitable outcomes (high unemployment and low economic status relative to host population) are likely to become frustrated and develop negative feelings towards the host nation population [11]. The UDRI model does not include a measure for the sentiment of refugees; however, the trend in the integration variables provide insight into the experiences of different groups within the model.

System's Mapping.

The Social subsystem of the UDRI model is not truly a structured subsystem, but a collection of variable functions that inform other parts of the model; in this way, it is similar to the Government and People subsystems. The existence of social variables that influence other parts of the UDRI model is supported by literature. The social variables that are used to influence other parts of the UDRI model and have not been previously been discussed are: *Language Labor Multiplier*, *Language Ability Multiplier*, and *Ethnic Network Multiplier*. The *Language Labor Multiplier* and *Language Ability Multiplier* are described in detail in the following quantitative modeling section of this subsystem. The *Ethnic Network Multiplier* is a variable that incorporates ethnic concentration to change the integration exams passing rates as well as the rate for persons moving from the low income sector to the middle income sector. This multiplier decreases all of these rates as the group population ratio in each district increases. Numerous studies (discussed in the literature review chapter) identify high ethnic concentration as factor that influences integration outcomes. As the *Ethnic Network Multiplier* increases, the passing rate for integration exams decreases. This is because high ethnic concentration is detrimental to the language ability of ethnic groups [18]. The *Ethnic Network Multiplier* decreases the rate that persons move from low income to middle income within a district. This is because a high concentration of co-ethnic individuals within a district has a positive impact on employment, but only within the district [15], [20]; therefore there is an increase in the unemployment of persons of minority ethnic groups because of increases competition for the available jobs within the ethnic network. Table 7 shows the uses of

Social subsystem variables, and the justification for the influence each has on other subsystems.

Table 7: Social subsystem variable uses and justification

Variable Name	Use(s)	Justification
Economic Integration LI	Education dropout rates, rates of choosing education type	OCW [62]–[64] Gijsberts [66]
Cognitive Dissonance	Attractiveness of districts	Bauer *et al* [18] Benenson [40]
Economic Tension	Attractiveness of districts	Andersen [17] Benenson [40]
Language Labor Multiplier	Movement Rates between sectors of income	Liu [15] Bevelander and Pendakur [16] Bevelander and Veenman [58]
Language Ability Multiplier	Integration Exam and NT2 pass rates	Beckhusen *et al* [20] Gijsberts *et al* [38]
Ethnic Network Multiplier	Movement rates between sectors of income, Integration Exam and NT2 pass rates	Liu [15] Bauer *et al* [18] Beckhusen *et al* [20]

Quantitative Modeling.

The quantitative validation of the Social subsystem was the most tenuous of all of the quantitative validation conducted in this thesis. This is because literature that makes conclusions about the effect of social phenomena generally does not provide numerical values. It is for this reason that most of the social influence lookup curves used in the UDRI model are linear. For example, the cognitive dissonance lookup takes the ratio of group in each district and compares it to the curve shown in Figure 13. The curve shape indicates that as the ratio of a group increases in an area, the cognitive dissonance decreases and vice versa.

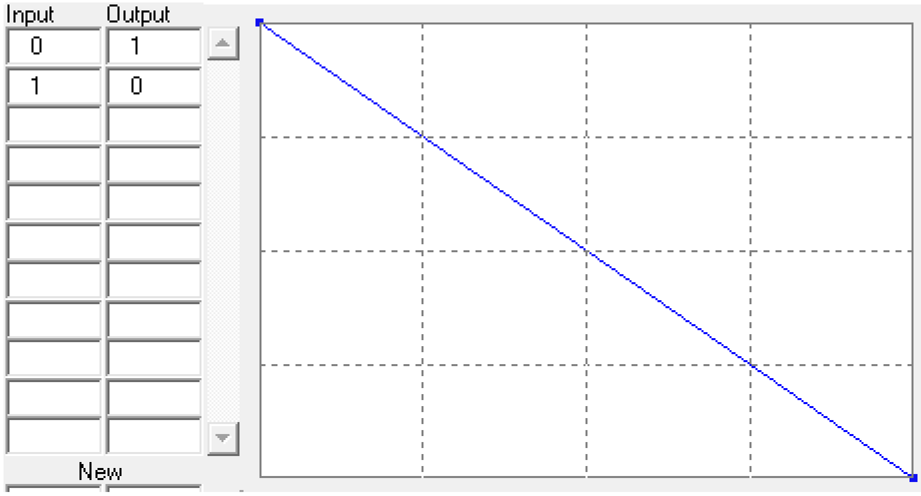

Figure 13: Cognitive dissonance lookup curve

The only non-linear curve unique to this thesis is the lookup curve that is used to determine the language labor multiplier and the language ability multiplier. This curve inputs the ratio of Dutch speakers and outputs a multiplier. As the ratio of Dutch speakers in each district by group increases the language labor multiplier increases; the language labor multiplier impacts the flow of groups from low income to middle income and from middle income to high income. The s-curve (shown in Figure 14) indicates that as the ratio of Dutch speakers increases, the rate that persons are able to move upwards through the sectors of income increases. There is a decreasing marginal effect of additional Dutch speakers as the ratio approaches one.

The language labor multiplier is based upon economic outcomes literature that notes the importance of language ability for individuals to gain employment and economic advancement.

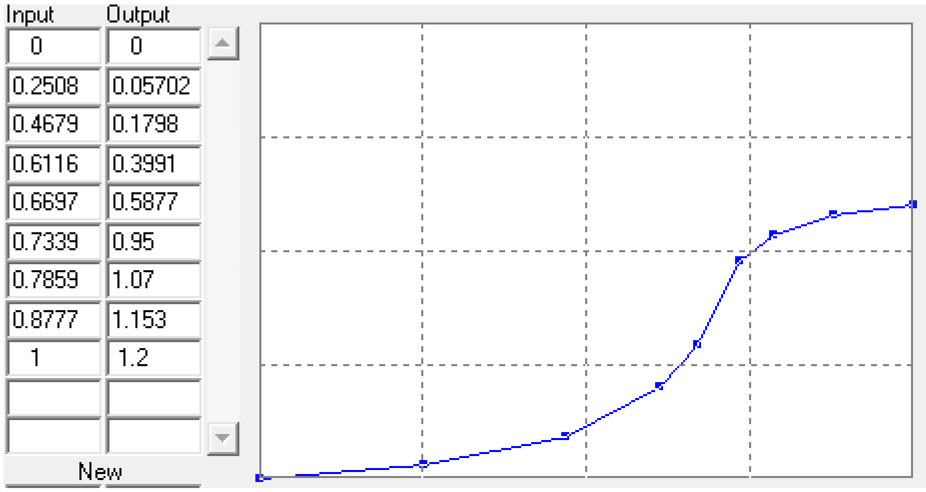

Figure 14: Language multiplier s-curve

The language ability multiplier uses the ratio of Dutch speakers in the entire district to influence the rate that persons pass the Civic Integration Exam and NT2. This multiplier uses the Dutch speakers of all groups in the district because as the amount of persons who speak Dutch increases, the more that people who live in the district are exposed to the Dutch language. This increased exposure is assumed to have a positive effect on the language skills of immigrants and refugees in the integration system.

Model Validation

System's Mapping.

When conducting system's mapping validation of the UDRI model, as a whole, the focus is on the way the subsystems are interconnected. The decision rules must be examined to determine if the system as a whole is valid. The overall flow of information and persons in the model is shown in Figure 15.

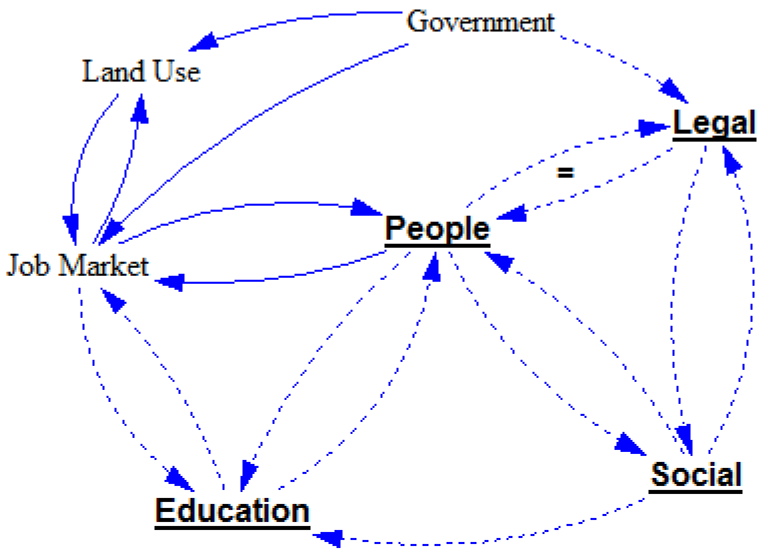

Figure 15: UDRI model system's mapping

The Legal subsystem represent the equal amount of *immigrants* and *refugees* that are in each district in the People subsystem (denoted by the equivalence sign). This parallel subsystems structure is valid because although persons move through each subsystem according to different decision rules, they amount of people in each subsystem are the same; therefore, the Legal and People subsystems inform each other to maintain equivalence and physical conservation.

The People subsystem is tracking all the levels of people that exist in the Job Market subsystem. The arrows between these two are solid because the People subsystem is an aggregation of the Job Market; and therefore, have not added or changed any information from the Sanders model. The People subsystem supplies the students for the Education subsystem who filter into the Job Market.

The Social subsystem contains integration measures that are informed by the People and Legal subsystems. Social subsystem variables inform the People, Legal, and Education subsystems. These connections are supported by literature (shown in Table 7).

Quantitative Modeling.

Part of the quantitative modeling validation has been conducted at the subsystem level. The constants of arrival rates, and construction rates were set according to available empirical data. Lookup curves for multipliers that were in the Sander's model were not modified because these describe the relative interactions between the different sectors of the Job Market. The constants have been tailored to a particular city, so the curves will still explain the interactions within the city that have been validated by both Forrester and Sanders. Quantitative validation of the UDRI model as a whole included examination of physical conservation, integration method, extreme conditions, and endogenous behavior reproduction testing.

Simulations of early versions of the UDRI model revealed that there were problems with maintaining physical conservation within the Education subsystem. In some districts there were very few students in particular education levels (e.g. *PRO/VSO*, especially *western-allochtonen refugee* students). Persons were leaving the city at such a high rate that there were occurrences where rounding errors resulted in negative persons being in a level. This of course is not possible. To fix the issue of conservation, checks were added into the balance equation of each education level to ensure that the net movement of individuals in the Job Market would only reduce the level to a minimum of zero. It should be noted that the population of *groups* in the *working population* of each district is greater than the *group education population*. Therefore, according to the UDRI model assumptions, it is possible for there to be persons of an *ethnic group* in a district but zero persons in levels of the education system.

The integration method was checked to ensure that using a different method would not create errors in the model or different results. The default integration method within Vensim uses the Euler method. The other integration option within Vensim uses a difference method. These two methods were compared using a capability within Vensim to compare the results of runs. Both methods produced identical results with runs that operated under the same assumptions. This study uses the Euler method for the experiments with the UDRI model.

Under extreme condition testing some of the variables from the Sanders's model initially produced errors when runs were completed using assumptions of the UDRI model in this thesis. Variables such as *MHOM MI housing obsolescence multiplier i* are calculated using the natural log of an input variable. The input variable for *MHOM MI housing obsolescence multiplier i* is *MHM MI housing multiplier i*. As the land of a city is used up, the *housing multipliers* go to zero. The natural log of zero is undefined, so a check was established for these natural log equations that uses the maximum of the input variable or a constant; the constant for each equation is the input that produces the lower boundary output variable of the lookup function. This check does not affect the results of the model runs because inputs outside the defined range of lookup curves are set at either the highest or lowest defined input (depending on whether the input variable is above or below the bounds, respectively).

The behavior modes that are important in this study are an increase in the economic divide between the different ethnic groups. Figure 16 shows the comparison of ratios in each sector of income in the city at large between *autochtonen* and *non-refugee, non-western allochtonen.* The UDRI model indicates that under the base model assumptions the economic gap is indeed widening between ethnic groups. The differences between groups in the sectors of income are small initially and then increase over time. Figure 17 shows this comparison between *autochtonen* and *non-refugee, western allochtonen*.

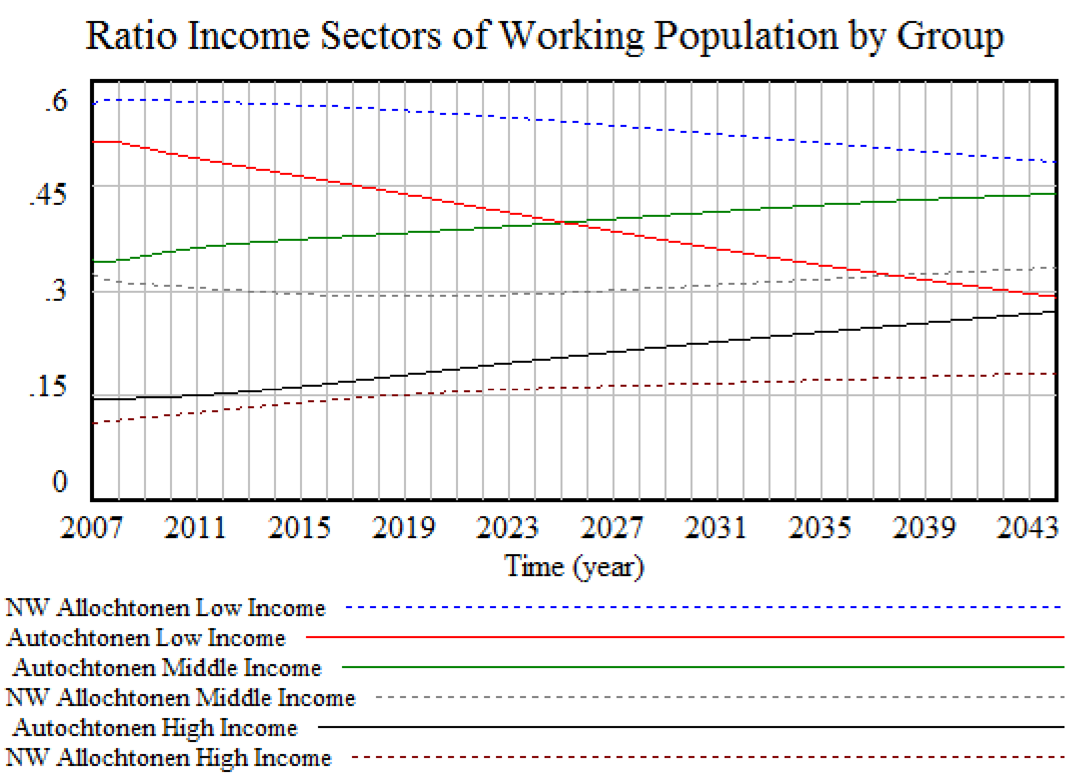

Figure 16: Sectors of income; autochtonen vs. non-refugee, non-western allochtonen

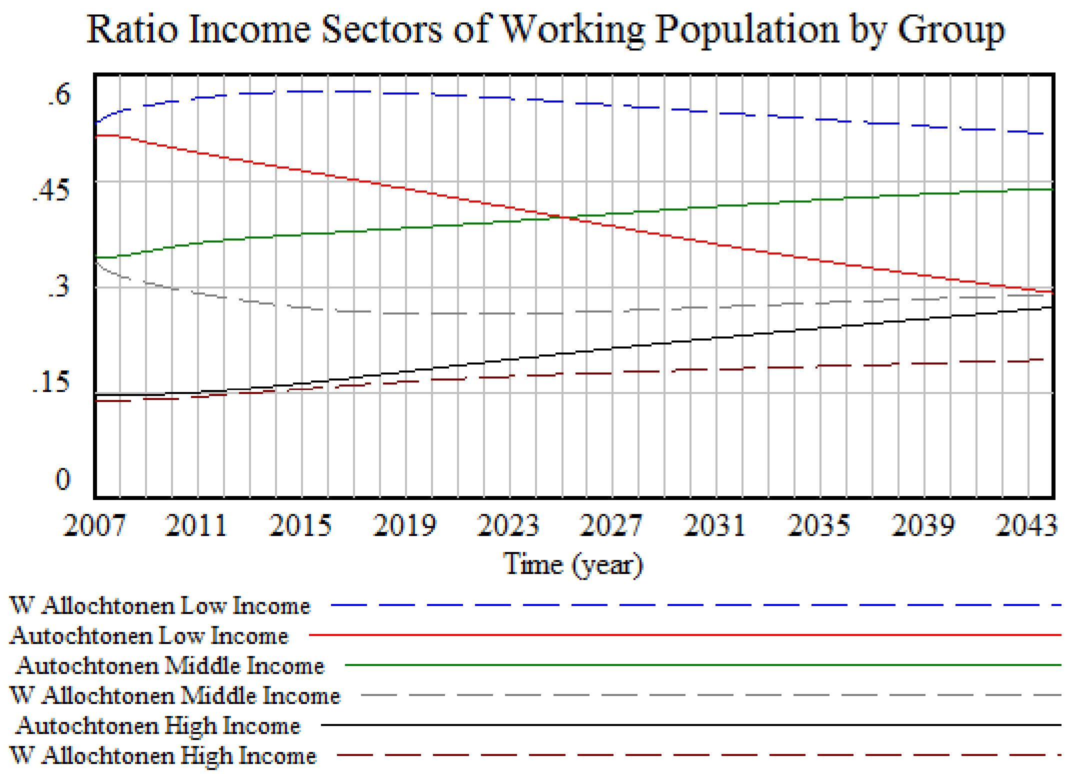

Figure 17: Sectors of income; autochtonen vs. non-refugee western allochtonen

The difference in economic outcomes between *refugees* and *autochtonen* are more extreme than those for their *non-refugee* counterparts. Figure 18 shows the comparison of ratios in each sector of income in the city at large between *autochtonen* and *non-western allochtonen refugees*; Figure 19 shows this same comparison for *western allochtonen refugees*. The graphs show the same patterns that exist for *non-refugee allochtonen.* The differences in economic outcomes of for *refugees* compared to *non-refugees* of the same *group* can be explained by three main factors: initialization, language ability, and *refugee* arrival assumptions. Each *refugee group* begins with no one in the *high income* sector and no *Dutch speakers*. Language ability is important for mobility between sectors. It is assumed that *refugees* arrive to the city and enter either the *low income* or *middle income* sector. The *non-refugee immigrants* arrive in proportion to the amount of persons who are in each sector. There is no flow from outside the system into the *high income* for *refugees*, so all *high income refugees* must come from within the system through the Job Market.

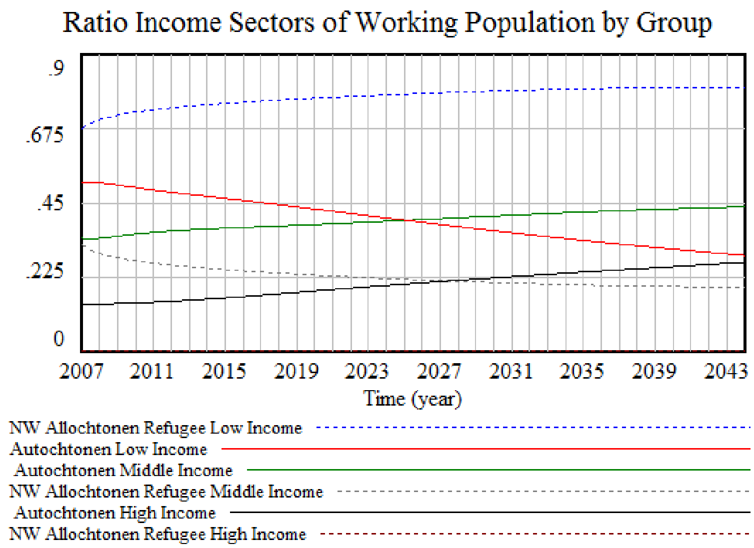

Figure 18: Sectors of income; autochtonen vs. non-western allochtonen refugee

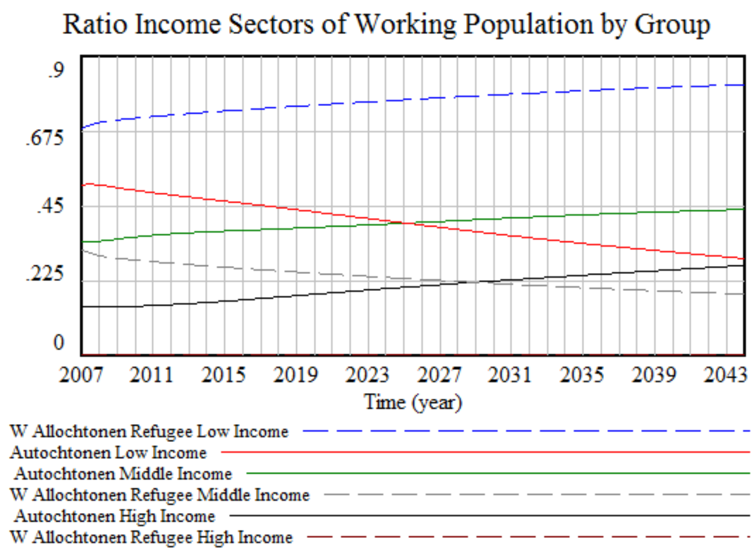

Figure 19: Sectors of income; autochtonen vs. western allochtonen refugee

The results of these economic outcome graphs should be analyzed based upon the trends they show and not for the values; in a real city the ratio of low income persons would likely not become less than the ratio of high income persons. The trends show that the UDRI model produces the system behavior of widening economic disparity described in refugee studies and presented in reports from Dutch national sources.

Another mode of behavior that is of interest is the changing distribution of ethnic groups throughout the city. Figure 20 shows the ratio of ethnic group by district for Centrum. The ratio of *non-western allochtonen* persons increases over time as the ratio of *autochtonen* persons decreases. The ratio of *western allochtonen* persons increases at a slower rate than *non-western allochtonen* persons. All of the districts display a similar trend. The ratio of group by district for each *allochtonen group* includes *refugees*. These trends of changing ethnic group distribution are evident in the CBS data. The economic and ethnic group modes of behavior occur at the same time so the phase of behaviors in the UDRI model is valid according to the endogenous behaviors of interest test.

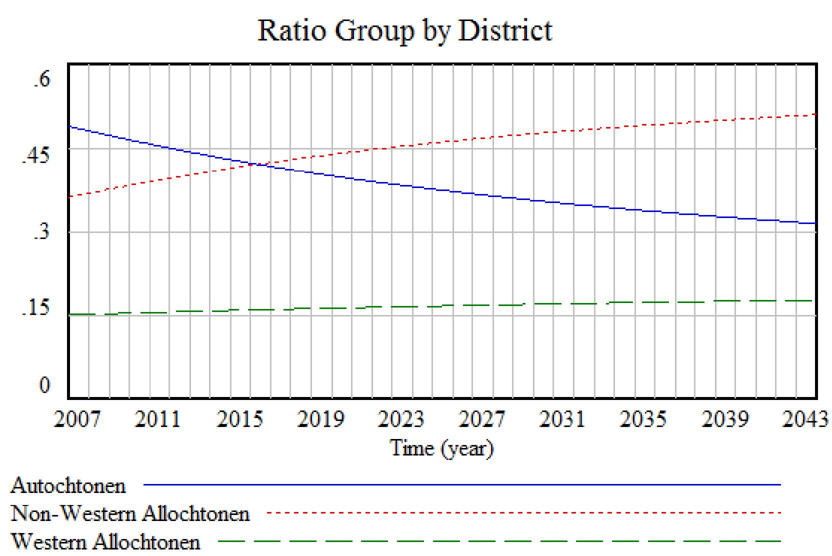

Figure 20: Ratio of group by district, Centrum

Hypothesis Testing.

Hypothesis testing validation for the UDRI model was comprised of policy decision rules, and behavior sensitivity analysis. The policy decision rules in the UDRI model capture the actions of the governmental authority. The municipal government of Rotterdam has the authority to effect economic policy such as job creation and job training. The municipal authorities can also regulate the classes of business activities by allowing certain industries to expand in open areas of the city. Other programs that fall under municipal authority include housing construction programs and language training programs.

A policy that was not used in the UDRI model was a policy that limited the amount of refugees or immigrants entering the city system. This study assumes that Rotterdam does not have the ability to refuse asylum seekers if the Dutch government has accepted their asylum application. This assumption is made because of the national government has authority over the municipal government within the Netherlands. This assumption would also make the analysis of the city system a trivial matter. Examining the integration of refugees when there are no new refugees in the system is a fruitless endeavor. This study recognizes the reality that refugee flow into cities exists and will continue into the future. Policy analysis should be done with this reality intact to understand the best ways to address the problem behavior modes; stopping refugees from entering the city ignores the issues surrounding integration instead of addressing them.

Behavior sensitivity testing is focused on analyzing the system behaviors when the assumptions about parameters in the model are changed. The focus for this testing is the general trends in the variables over time. If varying the value of a parameter over the range of reasonable values results in the disappearance of previously displayed model behaviors (or appearance of new ones), then the model is sensitive to that parameter value. This does not necessarily invalidate the parameter assumption. Finding sensitive parameters provides insight into the system being studied. Policy makers should understand that assumptions about sensitive parameters (as they exist in the real world) should be revisited to check the confidence in these values. The behavior sensitivity testing and uncertainty analysis was conducted using the built-in Vensim sensitivity analysis toolset. This process is explained in the following section uncertainty analysis section.

Uncertainty Analysis.

In a real-world system there is a degree of uncertainty that influences how processes function. Quantitative sensitivity testing focuses on the change in numerical results of a model when parameters are varied over the range of reasonable values. The range of reasonable values used can be determined using data analysis or expert opinion. For the purpose of the sensitivity testing in the UDRI model, the range of change in constants was from 75% to 125% of the value that is used in the baseline model. The constants used for sensitivity testing were the ones that are unique to the UDRI model, were calculated using empirical data, and affect the rate of processes. The list of constants used and their low, base, and high values are shown in Appendix A.

The sensitivity simulation tool within Vensim allows users to specify constants according to different probability distributions, select the method by which to change the constants, and choose which variables to save as output for each run of the simulation. Probability distributions available include, uniform, normal, and triangular probability distributions. The uniform distribution was used because this distribution only requires two parameters: a minimum value and a maximum value. There wasn't information available on the distribution of the constants that were calculated using CBS data. For this reason the simplest probability distribution was chosen to use for the sensitivity simulation. If more information were available, the UDRI model could be updated to use the appropriate probability distribution.

The options for changing the constants are the method that govern the sampling of the probability distributions. There are four options for sampling method: univariate, multivariate, Latin grid, and Latin hypercube. Latin grid and Latin hypercube sampling are discussed in the following forecasting/optimization section. The univariate method changes one constant at a time each run of the simulation while the others are held to their value in the baseline model. The multivariate method changes all factors simultaneously during each run of the simulation. For the purposes of the sensitivity validation of the UDRI model, multivariate was selected as the best option; multivariate sampling produces sensitivity results that display a wide range of possible variable results under uncertainty.

Behavior sensitivity validation only requires the inspection of general trends of the system. A multivariate sampling method can indicate the range of behaviors according to the uncertainty of all of the constants used. It is not necessary to understand which constant causes the most uncertainty at this point; the effect of specific input variables on output variables is investigated in the experiments described in the forecasting/optimization section. The multivariate method is appropriate for the quantitative sensitivity of the UDRI model as well. As previously mentioned, the particular values of variables in the UDRI model are not the focus, rather it is the relation of these values to each other that is important.

The final sensitivity simulation settings are the number of simulations and the seed number. 500 simulations was deemed sufficient to produce sensitivity results with large variation. The number of simulations was set at this number because the effect of individual factors was not a concern for sensitivity analysis testing; therefore, a large number of runs was needed, but not a number of runs that was determined through analytical means. The seed number is a value that initializes the random number stream used to sample constants during simulations; the seed used for the sensitivity simulation was 2007.

The graphical results of the sensitivity simulation indicate that the behavior is relatively insensitive to uncertainty in the constants tested. Figure 21 shows the sensitivity graphs for low income as a ratio of the each group population. There is a color scale to indicate the confidence bounds on the values; 50% indicates that half of the simulation runs lie within that region. The entire shaded region represents 100% of all simulation runs. The graphs in order of top to bottom represent: *autochtonen*, *non-western allochtonen*, and *western allochtonen*. Note that the *autochtonen group* does not have the same vertical scale as the other two graphs.

These graphs show that the mode of behavior of a widening gap between groups still exists, but uncertainty in the constants creates variation in the numerical results. The ratio of low income persons under uncertainty varies by as much as 10% for each ethnic group. However, neither *allochtonen group* range overlaps with the range of values for the *autochtonen group*. This indicates that the numerical results for economic outcomes are sensitive to uncertainty but do not change the relative values. The other sectors of income in all *groups* (including *refugees*) display the same trends that were seen in the baseline model and shown in Figure 16 and Figure 17.

The ethnic group distribution within districts was more sensitive to the uncertainty of constants. Figure 22 shows the sensitivity graphs for ratio of group by district for Centrum. The graphs from top to bottom show the groups are *autochtonen*, *non-western allochtonen*, and *western allochtonen*. Again, note that these graphs do not have the same vertical scale. The 50% interval exhibited the same trends as shown in Figure 20; however, some of the extreme observations indicate that the ratios by group exhibit the opposite behavior. This is most likely due to the changing *birth rates* and *arrival rates* for *immigrants* and *refugees*.

The sensitivity of the UDRI model demonstrates that under uncertainty the modes of behavior of a widening economic gap between ethnic groups and a redistribution of ethnic groups throughout the city are still present; the quantitative sensitivity increases as time passes. This makes sense, because the after the break-in period (redistribution according to pressures present at initialization) uncertainty in the constants results in simulation runs in which the rates carry on trends in diverging directions.

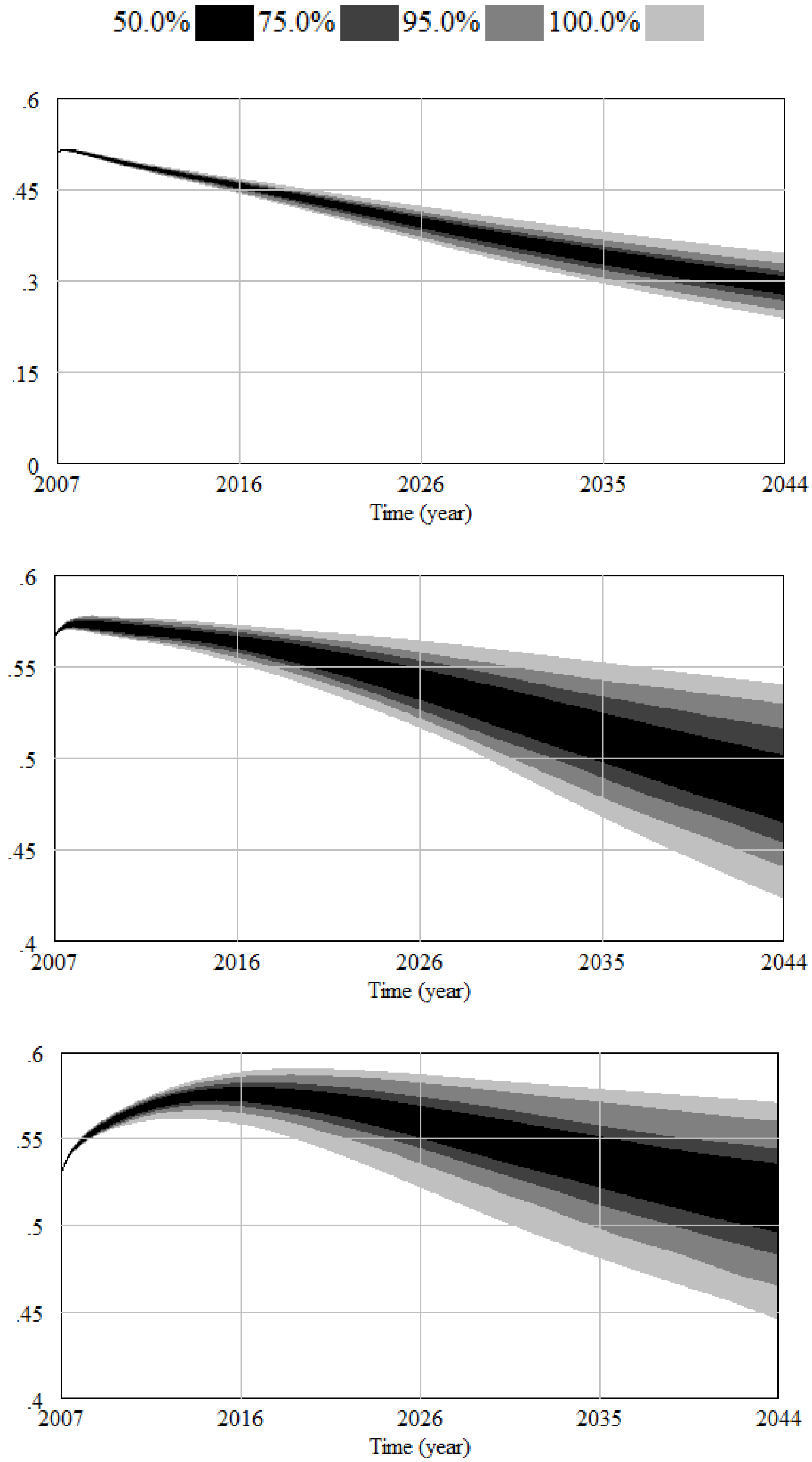

Figure 21: Sensitivity of ratio LI of group working population: autochtonen, non-western allochtonen, western allochtonen

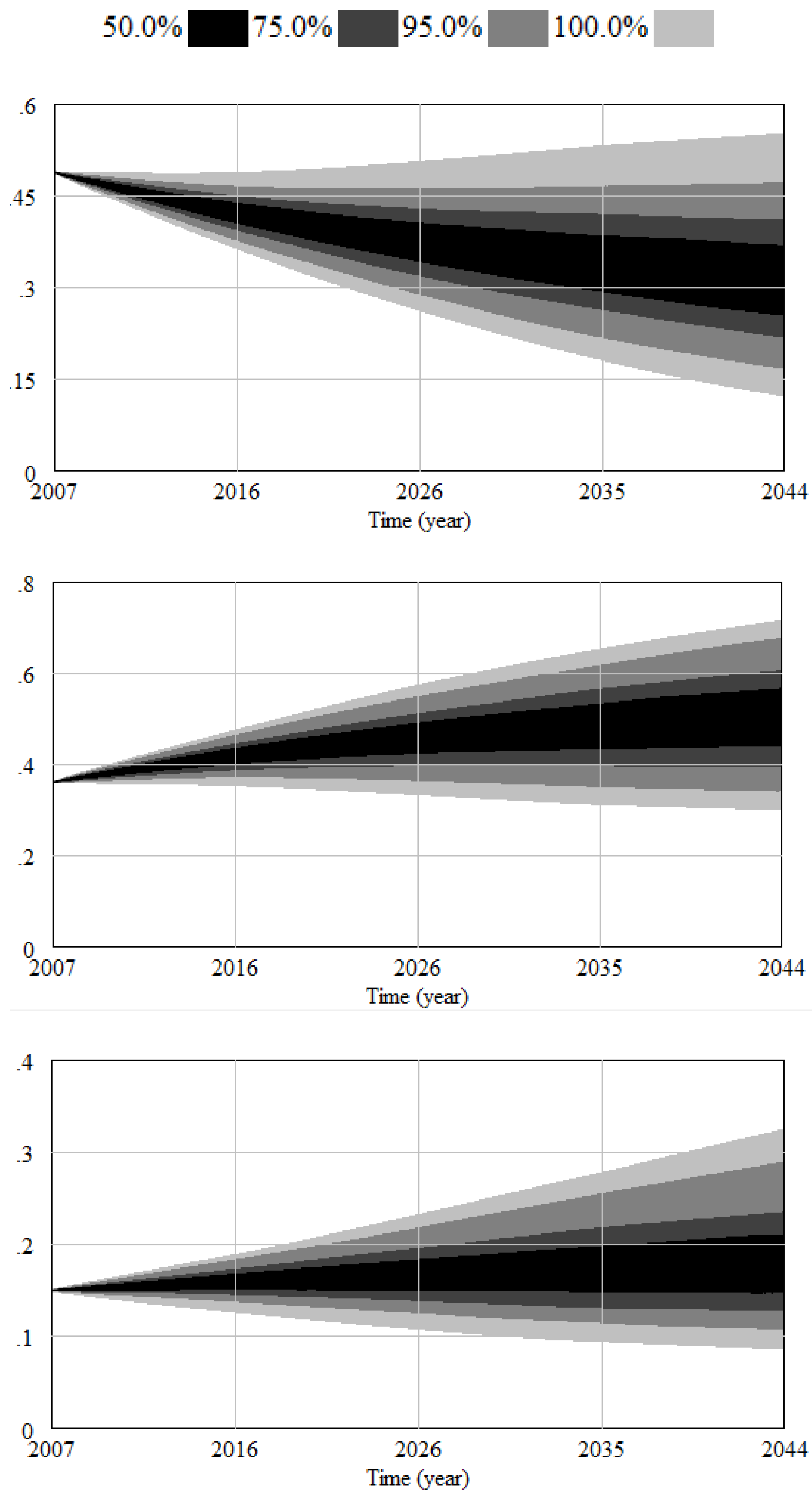

Figure 22: Sensitivity ratio group by district, Centrum: autochtonen, non-western allochtonen, western allochtonen

Forecasting/Optimization

The method used to conduct forecasting and optimization validation of the UDRI model was to use the government program rates endogenous to the model as input variables and then analyze the impact of these policies on the measures of integration. To narrow the focus of the experiments, two scenarios were considered: policy impact on policy impact on *refugee* integration (both *non-western* and *western allochtonen*), and *non-western allochtonen* integration (*non-refugee* and *refugee* combined). Each policy in the UDRI experiments is implemented beginning in the simulation year 2015.

The impact of policy on *refugees* is investigated because this *group* is the most socio-economic disadvantaged *group* and the flow of *refugees* is not necessarily regular; policy recommendations for improving outcomes and integration results for these individuals is a main focus of this study. The *non-western allochtonen group* is considered because this group had the greatest difference in economic sectors at initialization of the model; the outcomes of *non-refugees* and *refugees* from an ethnic group are connected because there are processes within the UDRI model that are informed by the state of the group as a whole. The experiments hypothesize that there may be differences in the policy recommendations when different combinations of groups are considered

A designed experiment was created to explore the two scenarios using a Latin Hypercube, space-filling design. This design was chosen because of the large number of policies considered. A Latin square design produces an experiment where every combination of factor levels is tested once; an experiment with two factors (A and B) that each have a different number of levels (A, 4 levels; B, 3 levels) would produce a design with 12 runs. An experiment with more factors or more levels would result in a larger design. With the UDRI model there are 7 programs that can each be changed by district or group. These program rates are continuous variables; therefore, covering the design space adequately would require at least three levels per factor (i.e. low, center, and high points). A design testing every combination of levels for every factor with each subscript would not be an effective approach in this preliminary study.

In a Latin hypercube design each factor has as many levels as there are runs. The levels are spaced evenly between the lower and upper bound of each factor. This design is able to adequately cover the design space by spreading out all factors across their ranges. This design is still able to detect main effects and low order interactions between factors with much fewer runs than a Latin square design. The design matrix for the Latin hypercube experimental design was generated using the JMP space filling design tool. For each experiment the designed experiment used a Latin hypercube design with 480 runs. The factors and responses for each experiment is shown in Appendix A.

Summary

Model validation is a significant part of the process of system dynamics modeling. Assumptions made in the modeling process are an abstraction of the real system; however, no model of a real-world system is perfect. It should be noted, however, that if more accurate data is available or became available, the relationships could be updated. The UDRI model is valid for the purpose of exploring the behavior of city system with refugee flow and the impact of policy on integration. The city of Rotterdam has been used as a framework for the UDRI model; it should be reiterated that this city model is not a predictive model of future behavior. The important conclusions from the experimental results should be the direction of trends and sign of coefficients of influential variables. The experimental results are discussed in the following analysis and results chapter.

V. Analysis and Results

Overview

This chapter contains the results from the two policy analysis experiments described at the end of the model development chapter. The significant programs for explaining variation in the integration response were found using regression of all main effects. Results of analysis of variance (ANOVA) models for each measure of integration are discussed in conjunction with sensitivity graphs. The sensitivity graphs (generated in Vensim) are shown for non-western allochtonen refugees to illustrate the range of values for each measure of integration. The y-axis of each graph shows the level of integration; a value of one represents full integration. Values less than one indicate that there is underrepresentation of individuals from the ethnic group in a particular measure; a value greater than one indicates overrepresentation. The sensitivity graphs show the pre-policy trajectory of the integration measure, indicated by a black line. Starting in the simulation year 2015 government programs are initiated. The variability in the integration measures over time is indicated by the shaded bands. The integration of non-western allochtonen refugees is shown throughout this chapter to maintain consistency and allow for the comparison of results between experiments.

Results and Discussion

Experiment 1: Refugee Focus.

The first experiment used policy only directed towards the two refugee groups. The impacts of government programs differ between the measures of integration. Social integration is most affected by the learning rate of language programs. ANOVA with *language program rate [nw-allochtonen refugee]* as the only variable results in a significant model (i.e., *F-Ratio = 22621.07, p-value <0.0001*) with an R-square value of 0.979. These results are intuitive. The social integration measure is equivalent to the city-wide language ability of each group; therefore, an increase in the language training program causes an increase in Dutch speakers and social integration. Figure 23 shows the first experiment sensitivity graph of social integration for non-western refugees. The range of values for social integration of each group are higher than the base model (that had no programs implemented).

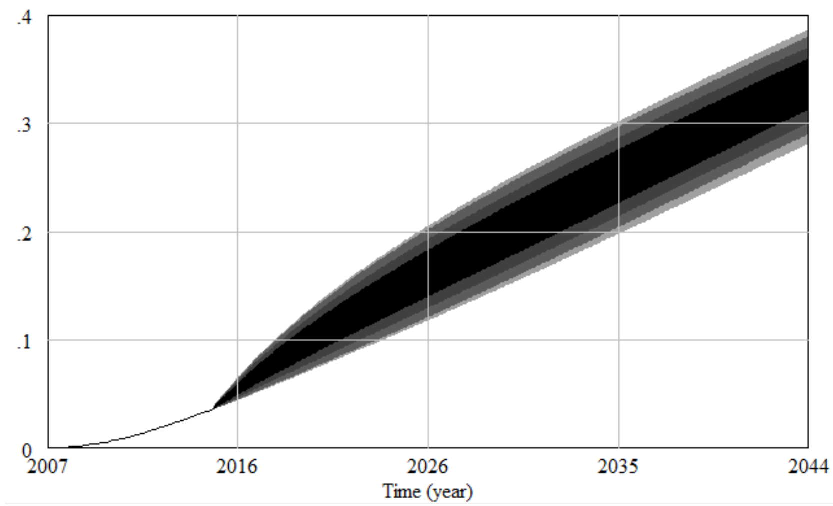

Figure 23: Experiment 1 social integration sensitivity graph, non-western allochtonen refugees

The effect of government programs on the legal integration of refugees is more complicated. ANOVA with legal integration indicates that a model with *language program rate [nw-allochtonen refugee]*, *low income housing construction rate [i]* (D5, D6, D8, D10, D11), and *middle income housing construction rate [i]* (D5, D6, D10, D11) results in a significant model (i.e., *F-Ratio = 479.53, p-value < 0.0001*) with and R-square of 0.911. Low income housing construction in districts such as Hillegersberg-

Schiebroek and Kranlingen-Crooswijk creates opportunities for low income individuals to move there. Refugees who move outside of districts with a high concentration of co-ethnic persons are able to escape the isolating effects of the ethnic network multiplier. Language programs coupled with the diminished ethnic network effect results in an increased language ability and therefore an increased rate of refugees who are able to complete their integration requirements and legally integrate. There effects of middle income housing construction on legal integration are negative. As land is being occupied by middle income housing, there is less area in these districts for low income individuals. The low income individuals do not have as much opportunity to leave their district and cannot gain from the benefit of leaving the ethnic network. Figure 24 shows the first experiment legal integration of non-western allochtonen refugees. Note that information about the legal status of individuals according to ethnic group was not publically available. The legal integration measure shows a decreasing trend at the beginning of the model simulation. This is due to a model burn-in period; therefore, the reversal of this trend is not directly due to policy implementation in the model.

The economic integration of refugees was the most quantitatively sensitive to policy program rates. Significant factors for explaining variation in economic integration were the labor training programs. ANOVA with economic integration of middle income persons indicates that a model with *low income training rate [nw-allochtonen refugee]*, *middle income training rate [nw-allochtonen refugee]*, *low income training rate [nw-allochtonen refugee]* squared, and the product of *low income training rate [nw-allochtonen refugee]* and *middle income training rate [nw-allochtonen refugee]* results in a significant model (i.e., *F-Ratio = 16809.75, p-value < 0.0001*) with an R-square of 0.993.

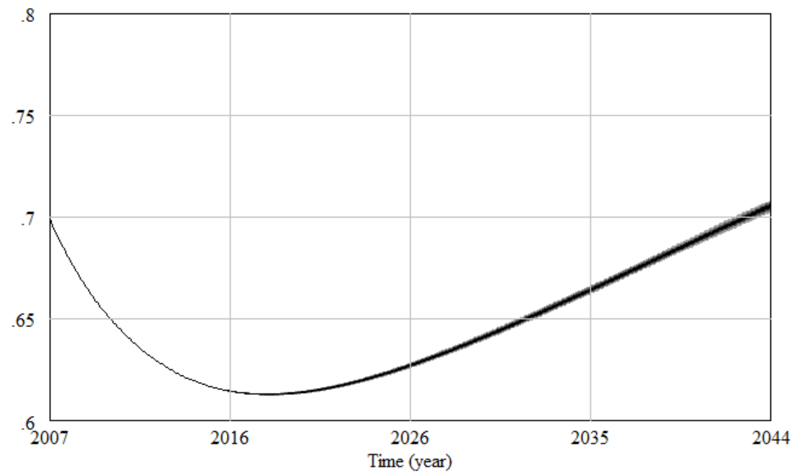

Figure 24: Experiment 1 legal integration sensitivity graph, non-western allochtonen refugees

The labor training programs directly increases the amount of people who move up in socio-economic status; therefore, the effect of *low income training rate [nw-allochtonen refugee]* is intuitively positive. The effect of *middle income training rate [nw-allochtonen refugee]* is negative because as people leave the middle income sector and go to the high income sector, the ratio of middle income relative to the group population decreases. The estimated effect of *Low income training rate [nw-allochtonen refugee]* squared is negative because as people leave the low income sector, there are fewer people in the low income sector to move into the middle income sector. The interaction effect between programs indicates that as the rate of low income persons entering the middle income sector increases, there population of middle income persons increases; the larger population of middle income individuals results in an increase in the amount of people who will leave middle income. The effects of policy on economic integration for low income and middle income non-western allochtonen refugees are shown in Figure 25and Figure 26, respectively. As more persons are trained and learn the language, more persons move from low income to middle income. The upward mobility of people can be seen in the complimentary shapes for Figure 25 and Figure 26.

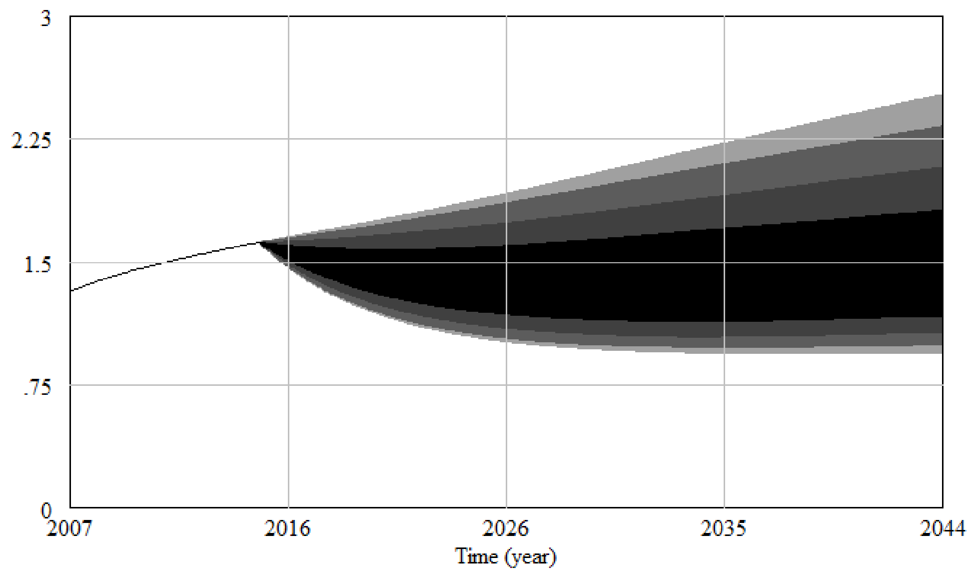

Figure 25: Experiment 1 low income economic integration sensitivity graph, non-western allochtonen refugees

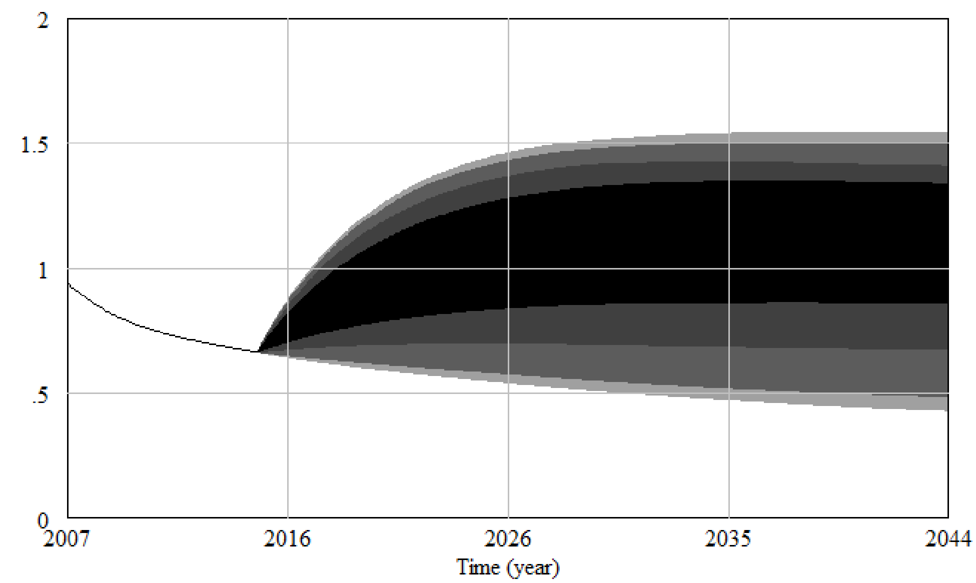

Figure 26: Experiment 1 middle income economic integration sensitivity graph, non-western allochtonen refugees

Experiment 2: Non-western Allochtonen Focus.

The second experiment used policy that was directed towards both refugee and non-refugee non-western allochtonen. To compare the results from experiment 1, the same measures of integration for non-western allochtonen refugees are shown in figures throughout this section.

The social integration of non-western allochtonen refugees in experiment 2 approximately follows the same trajectory as the social integration in experiment 1. ANOVA with *language program rate [nw-allochtonen refugee]*, *language program rate [nw-allochtonen]*, *low income training rate [nw-allochtonen refugee]*, and *low income training rate [nw-allochtonen]* results in a significant model (i.e., *F-Ratio = 199.32*, *p-value < 0.001*) with an R-square of 0.455. Figure 27 shows the second experiment social integration sensitivity graph for non-western allochtonen refugees. Note that Figure 23 and Figure 27 have different scales on the y-axis.

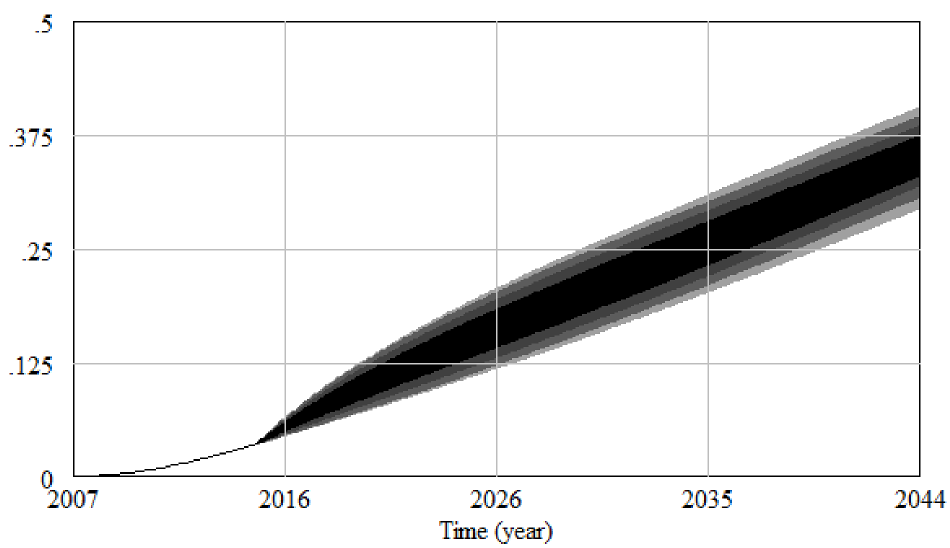

Figure 27: Experiment 2 social integration sensitivity graph, non-western allochtonen refugees

The effect of government policy on the legal integration of refugees in experiment 1 was minimal. Figure 24 indicates that there is not much variation in legal integration of non-western allochtonen refugees with the implementation of policy directed towards refugees. In the second experiment, the legal integration of the non-western allochtonen refugees is more responsive to government programs. Figure 28 shows the variation in legal integration. ANOVA with *low income training rate [nw-allochtonen refugee]*, *low income training rate [nw-allochtonen]*, *middle income training rate [nw-allochtonen refugee]*, and *middle income training rate [nw-allochtonen]* results in a significant model (i.e. *F-Ratio = 189.39, p-value < 0.0001*) with an R-square of 0.442. The difference in the effects between experiments can be explained by the influence of the non-refugee, non-western allochtonen population. The population of non-refugee, non-western allochtonen is much large in magnitude than the refugee population for the same ethnic group. For this reason, implementing programs for non-refugee individuals creates other behaviors in the model that are not explained by the ANOVA model.

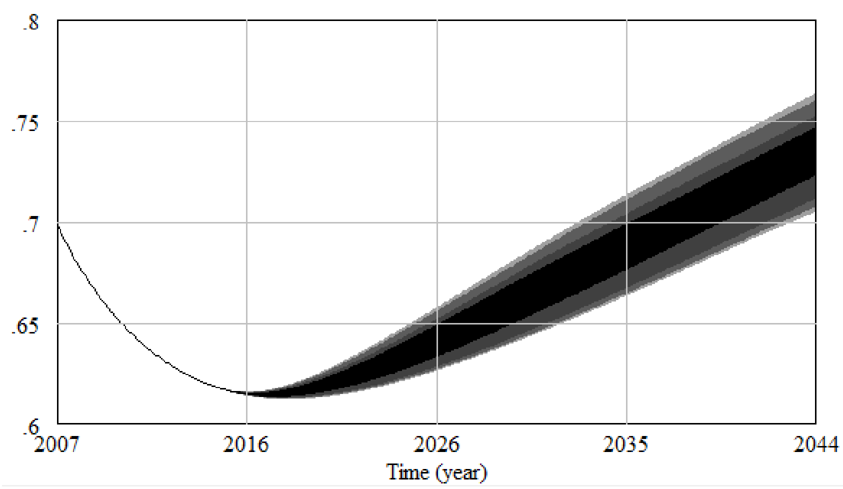

Figure 28: Experiment 2 legal integration sensitivity graph, non-western allochtonen refugees

The economic integration for non-western refugees in experiment 2 shows similar patterns to the results in experiment 1. ANOVA with economic integration of middle income persons indicates that a model with *low income training rate [nw-allochtonen refugee]* and *low income training rate [nw-allochtonen]* results in a significant model (i.e., *F-Ratio = 966.15, p-value < 0.0001*) with an R-square of 0.668. Figure 29 shows the economic integration of low income non-western allochtonen refugees. Compared to the results in Figure 25, in extreme cases, there are fewer low income persons relative to their population in experiment 2. This suggests that there is an additive effect on economic integration of refugees when government policy is directed towards non-refugees of the same ethnic group. Figure 30 shows the economic integration of middle income western allochtonen refugees.

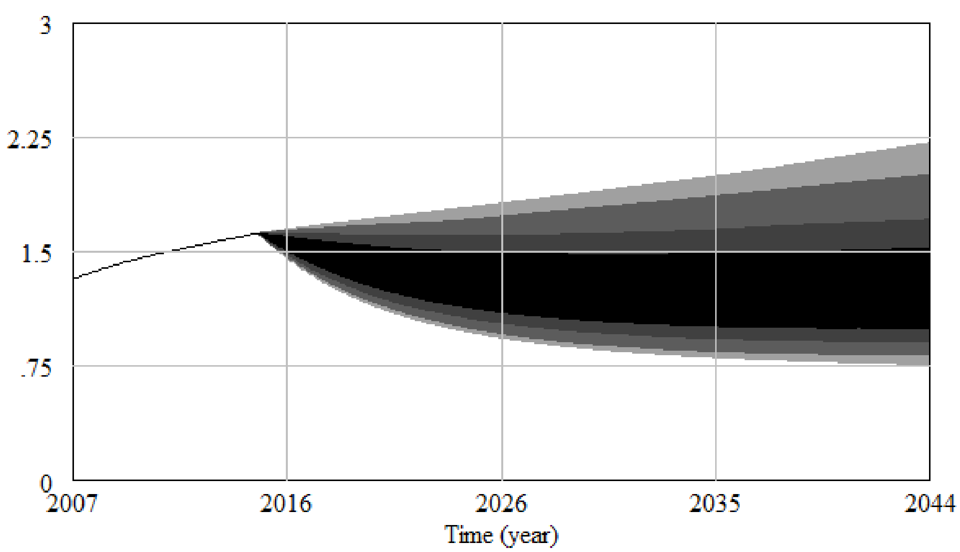

Figure 29: Experiment 2 low income economic integration sensitivity graph, non-western allochtonen refugees

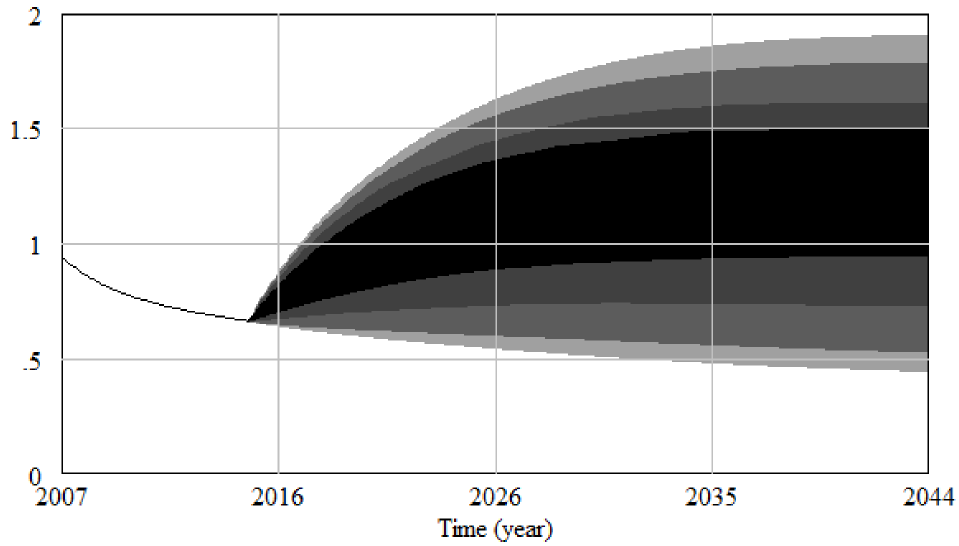

Figure 30: Experiment 2 middle income economic integration sensitivity graph, non-western allochtonen refugees

Summary

Through experimentation it has been shown that the model indicates that government programs directed towards refugees can have a positive effect on the measures of integration for these groups. The results of the experiment also indicate that there is an additional positive affect on the integration of refugees if policy is implemented on non-refugee individuals of the same ethnic group. The analytical results in this analysis and results chapter inform the policy recommendations made in the following conclusions and recommendations chapter.

VI. Conclusions and Recommendations

Overview

The conclusions of this study are framed as answers to the research questions that were asked at the end of the introduction chapter. The research questions are repeated and addressed in the following subsection. The responses are a combination of information from the literature review, model development, and analysis and results chapters.

Conclusions of Research

1. Which factors are the drivers of integration in a city system?

   The literature review indicates that economic intervention is an appropriate method to increase integration of individuals within a city system. This was shown to be the case within the UDRI model. In addition to economic intervention, language training seems to have quite a large effect on integration of all types. The impact of language ability on job market outcomes (as shown in literature) explains this effect. Additionally, efforts to redistribute persons of lower income (of all ethnic groups) relieves the pressures of competition for low income jobs within crowded districts and increases economic outcomes for these individuals.

2. What are the effects of changing assumptions on city system behavior?

   The UDRI model is fairly quantitatively sensitive to changes of the assumed parameters and rates. However, it is not very behaviorally sensitive. This indicates that the parameters used for this model should be reviewed to assure confidence in the values. Another method of dealing with uncertainty of parameters is to embrace it by modeling the parameters as probability distributions. Additional available data (at the appropriate fidelity) should be used to update the parameters within the UDRI model.

3. Which government policies are best suited to address problems with integration?

   The model indicates that the government policies that address social, legal and economic integration are language programs, labor training programs, and low cost housing construction programs. The UDRI model indicates that these programs in combination can increase the integration of individuals within a city system. The policies should focus on both refugee and non-refugee populations of disadvantaged persons to take advantage of the additive effects of improving outcomes for an entire ethnic group.

Limitations of Results

The applicability of the results of the UDRI model are limited by the modeling method, data availability, and the modeling assumptions. The system dynamics model in this study represents the decisions and movements of individuals throughout the city system; yet, these are the decisions and movements of the average person. The parameters calculated from empirical data are representations of the average value for people within the city. Even if there is data available to determine parameters for groups, the parameters represent the average person within that group. It should not be forgotten that in a population of people, there are some who would act similar to the average person while others would not. System dynamics is not as well-suited for modeling individual decision making processes as some other methods are (e.g. agent-based simulation). The UDRI model is a valid representation of a city; nonetheless, the limitations of system dynamics must be understood to appropriately interpret the results of this study.

It has been mentioned previously throughout this study that if there were more data available or data available with higher granularity, then the model could be updated to reflect this information. Not all of the data used within the model development is representative of the district level in the city of Rotterdam. In each case, the next best, available replacement has been used to populate the model. This study is conducted with the understanding that more accurate data would result in a more accurate model; accordingly, the parameters that were determined using data other than Rotterdam, district-level, sources were clearly denoted.

Data availability is one of the causal factors of the modeling assumptions made during model development and validation. In the absence of an appropriate, available replacement for parameters or structures, the assumption was made that the value or form remained unchanged from the Sanders model. Changes to decision rules were made because there was information to support that there existed a difference in the Rotterdam city system and that it was appropriate and necessary for the purpose of this study to model that difference. The conclusions made in this study should be viewed through the lens of the limitations described within this section.

Recommendations for Future Research

Recommendations for future research follow two main paths. The first vein of future research involves refining the UDRI model. There are plenty of opportunities to add to this initial formulation of the model. Topics for consideration should include gender-related differences in socio-economic outcomes of refugees, variables that describe sentiments between groups of people, and the implementation of a transportation system. The current UDRI formulation does not take into account marital status or sex of individuals. Research within the field of refugee studies indicates that there are differences in the social and economic outcomes between male and female asylum seekers [10], [16], [30]. It would be a worthwhile excursion to add gender dynamics to the UDRI model.

There are opportunities within the UDRI model to create and implement implied attitude variables using the information that is already in the system. These variables could use the differences (or trends in differences) in economic outcomes between groups of people to quantify feelings. Increased economic disparity between groups would likely created increased frustration for disadvantaged groups [11]. An increasingly frustrated person would potentially act according to different decision rules than a person who is satisfied with their personal circumstances. Adding attitude variables to the UDRI model would augment the existing social integration measure and add a realistic and relevant component to refugee integration.

The implementation of a transportation system within the city would allow for the relaxation of the non-commuting assumption. In this way, the model would be able to represent the choices people make about whether or not they would like to commute to their place of employment. This added transportation system should include public transportation options. Many persons of lower socio-economic status rely on public transportation systems to commute to and from work. Decisions about transportation options are interrelated with the infrastructure impacts within the city. Adding a transportation system would capture this dynamic.

The second path of recommended future research is in the field of refugee studies. This study is focused on refugees, there are other millions of other displaced persons who are not addressed in the UDRI model. All types of displaced persons are vulnerable; these people deserve value-added research to help understand their plight and recommend solutions to the complex issues surrounding displacement. There are other types of displaced persons who are likely to become more prominent in the future; environmental refugees are a group of persons that will in all likelihood increase in size as pressures from drought, rising water levels, and other climate shifts threaten established communities of people. Researchers from all fields of study can and should contribute to understanding issues surrounding displaced persons and strive to improve the conditions for vulnerable people.

Significance of Research

This research offers insights into the dynamics within a city that is affected by refugee flow. The literature review and modeling in this study further the understanding of the ways that refugees are affected as they move into cities. Although the UDRI model has limitations that diminish its realism in some ways, there is still value added for thinking models that bring understanding to complex social issues. Davis and O’Mahony of RAND Corporation [67] among others have identified multiple values and benefits gained from the process of developing data-driven, semi-quantitative models. Models that describe complex processes are valuable in themselves as thinking models; these models help individuals understand the interactions between components of a system without the need for a high level of expertise in technical fields (e.g.. mathematics, computer science, and so forth) [67]. Models such as the UDRI are useful because of the feasibility of describing and handling social and human components. The UDRI model has plenty of room for improvements; nonetheless, in its current form, there is value added in the contribution to understanding of the problems surrounding refugees. The model provides a foundation for capturing social science insights that can be a guide to data needs for quantification. The act of modeling provides value in and of itself.

Summary

The UDRI model is a preliminary attempt to bring value and insight to the field of refugee studies through the use of operations research techniques. This thesis is an early step in building the body of knowledge in the fields of operations research and refugee studies. Further research is certainly recommended to expand upon the framework of this pilot study. Hopefully, this study has increased the awareness of challenges faced by displaced persons and has inspired a desire for those reading to use their talents and abilities for the benefit of others.

Appendix A: Supplemental Tables

Table 8: District geographic coordinates

District	Coordinates
Centrum	51.918159, 4.473938
Delfshaven	51.907092, 4.451218
Overschie	51.938306, 4.431423
Noord	51.931931, 4.459926
Hillegersberg-Schiebroek	51.952033, 4.489160
Kranlingen-Crooswijk	51.918943, 4.522730
Feijenoord	51.895858, 4.502800
Ijsselmonde	51.886354, 4.543441
Pernis	51.888720, 4.389092
Prins Alexander	51.960537, 4.542634
Charlois	51.889008, 4.466833
Hoogvliet	51.861595, 4.358007
Hoek van Holland	51.980651, 4.134087
Rozenburg	51.904419, 4.247127

Table 9: Sensitivity analysis constants and values

Constant Name	Low Value	Base Value	High Value
Birth Rate [autochtonen]	0.00218	0.00291	0.00364
Birth Rate [nw-allochtonen]	0.00384	0.00513	0.00641
Birth Rate [w-allochtonen]	0.00308	0.00411	0.00514
Business Opening Normal [A]	0.0035	0.0046	0.0058
Business Opening Normal [B-F]	0.0290	0.0386	0.0483
Business Opening Normal [G+I]	0.0152	0.0202	0.0253
Business Opening Normal [H+J]	0.0404	0.0539	0.0674
Business Opening Normal [K-L]	0.0173	0.0231	0.0289
Business Opening Normal [M-N]	0.0497	0.0662	0.0828
Business Opening Normal [R-U]	0.0443	0.0591	0.0739
Housing Construction Normal [single]	0.002	0.003	0.004
Housing Construction Normal [multi]	0.004	0.006	0.008
Housing Obsolescence Normal	0.0002	0.0003	0.0004
Immigrant Arrival Rate constant[nw-allochtonen]	0.0098	0.013	0.016
Immigrant Arrival Rate constant[w-allochtonen]	0.0029	0.0039	0.0049
Integration Exam Pass Rate constant	0.461	0.615	0.769
NT2 Pass Rate constant	0.461	0.615	0.769

Refugee Arrival Normal[i, nw-allochtonen refugee]	6.26	8.35	10.44
Refugee Arrival Normal[i, w-allochtonen refugee]	0.3	0.4	0.5
Working Population Arrival Normal [non refugee]	0.028	0.037	0.046
Working Population Departures Normal[non refugee]	0.035	0.047	0.059
Working Population internal out-of-zone movement normal	0.021	0.028	0.035

Table 10: Experiment factors

Experiment 1	Experiment 2	Range
HHCR HI housing construction rate[D1]	HHCR HI housing construction rate[D1]	[0, 0.01]
HHCR HI housing construction rate[D2]	HHCR HI housing construction rate[D2]	[0, 0.01]
HHCR HI housing construction rate[D3]	HHCR HI housing construction rate[D3]	[0, 0.01]
HHCR HI housing construction rate[D4]	HHCR HI housing construction rate[D4]	[0, 0.01]
HHCR HI housing construction rate[D5]	HHCR HI housing construction rate[D5]	[0, 0.01]
HHCR HI housing construction rate[D6]	HHCR HI housing construction rate[D6]	[0, 0.01]
HHCR HI housing construction rate[D7]	HHCR HI housing construction rate[D7]	[0, 0.01]
HHCR HI housing construction rate[D8]	HHCR HI housing construction rate[D8]	[0, 0.01]
HHCR HI housing construction rate[D9]	HHCR HI housing construction rate[D9]	[0, 0.01]
HHCR HI housing construction rate[D10]	HHCR HI housing construction rate[D10]	[0, 0.01]
HHCR HI housing construction rate[D11]	HHCR HI housing construction rate[D11]	[0, 0.01]
HHCR HI housing construction rate[D12]	HHCR HI housing construction rate[D12]	[0, 0.01]
HHCR HI housing construction rate[D13]	HHCR HI housing construction rate[D13]	[0, 0.01]
HHCR HI housing construction rate[D14]	HHCR HI housing construction rate[D14]	[0, 0.01]
Language Program Rate["w-allochtonen refugee"]	Language Program Rate["nw-allochtonen refugee"]	[0, 1.6]
Language Program Rate["nw-allochtonen refugee"]	Language Program Rate["nw-allochtonen "]	[0, 1.6]
LHCR LI housing construction rate[D1]	LHCR LI housing construction rate[D1]	[0, 0.01]
LHCR LI housing construction rate[D2]	LHCR LI housing construction rate[D2]	[0, 0.01]
LHCR LI housing construction rate[D3]	LHCR LI housing construction rate[D3]	[0, 0.01]
LHCR LI housing construction rate[D4]	LHCR LI housing construction rate[D4]	[0, 0.01]
LHCR LI housing construction rate[D5]	LHCR LI housing construction rate[D5]	[0, 0.01]
LHCR LI housing construction rate[D6]	LHCR LI housing construction rate[D6]	[0, 0.01]
LHCR LI housing construction rate[D7]	LHCR LI housing construction rate[D7]	[0, 0.01]
LHCR LI housing construction rate[D8]	LHCR LI housing construction rate[D8]	[0, 0.01]
LHCR LI housing construction rate[D9]	LHCR LI housing construction rate[D9]	[0, 0.01]
LHCR LI housing construction rate[D10]	LHCR LI housing construction rate[D10]	[0, 0.01]
LHCR LI housing construction rate[D11]	LHCR LI housing construction rate[D11]	[0, 0.01]

LHCR LI housing construction rate[D12]	LHCR LI housing construction rate[D12]	[0, 0.01]
LHCR LI housing construction rate[D13]	LHCR LI housing construction rate[D13]	[0, 0.01]
LHCR LI housing construction rate[D14]	LHCR LI housing construction rate[D14]	[0, 0.01]
LTR LI training rate["w-allochtonen refugee"]	LTR LI training rate["nw-allochtonen refugee"]	[0, 0.1]
LTR LI training rate["nw-allochtonen refugee"]	LTR LI training rate["nw-allochtonen"]	[0, 0.1]
MHCR MI housing construction rate[D1]	MHCR MI housing construction rate[D1]	[0, 0.01]
MHCR MI housing construction rate[D2]	MHCR MI housing construction rate[D2]	[0, 0.01]
MHCR MI housing construction rate[D3]	MHCR MI housing construction rate[D3]	[0, 0.01]
MHCR MI housing construction rate[D4]	MHCR MI housing construction rate[D4]	[0, 0.01]
MHCR MI housing construction rate[D5]	MHCR MI housing construction rate[D5]	[0, 0.01]
MHCR MI housing construction rate[D6]	MHCR MI housing construction rate[D6]	[0, 0.01]
MHCR MI housing construction rate[D7]	MHCR MI housing construction rate[D7]	[0, 0.01]
MHCR MI housing construction rate[D8]	MHCR MI housing construction rate[D8]	[0, 0.01]
MHCR MI housing construction rate[D9]	MHCR MI housing construction rate[D9]	[0, 0.01]
MHCR MI housing construction rate[D10]	MHCR MI housing construction rate[D10]	[0, 0.01]
MHCR MI housing construction rate[D11]	MHCR MI housing construction rate[D11]	[0, 0.01]
MHCR MI housing construction rate[D12]	MHCR MI housing construction rate[D12]	[0, 0.01]
MHCR MI housing construction rate[D13]	MHCR MI housing construction rate[D13]	[0, 0.01]
MHCR MI housing construction rate[D14]	MHCR MI housing construction rate[D14]	[0, 0.01]
MTR MI training rate["w-allochtonen refugee"]	MTR MI training rate["nw-allochtonen refugee"]	[0, 0.1]
MTR MI training rate["nw-allochtonen refugee"]	MTR MI training rate["nw-allochtonen"]	[0, 0.1]

Table 11: Experiment responses

Experiment 1	Experiment 2
Social Integration [w allochtonen refugee]	Social Integration [nw allochtonen]
Social Integration [nw allochtonen refugee]	Social Integration [nw allochtonen refugee]
Economic Integration LI [w allochtonen refugee]	Economic Integration LI [nw allochtonen]
Economic Integration LI [nw allochtonen refugee]	Economic Integration LI [nw allochtonen refugee]
Economic Integration MI [w allochtonen refugee]	Economic Integration MI [nw allochtonen]
Economic Integration MI [nw allochtonen refugee]	Economic Integration MI [nw allochtonen refugee]
Economic Integration HI [w allochtonen refugee]	Economic Integration HI [nw allochtonen]
Economic Integration HI [nw allochtonen refugee]	Economic Integration HI [nw allochtonen refugee]
Legal Integration Total [w allochtonen refugee]	Legal Integration Total [nw allochtonen]
Legal Integration Total [nw allochtonen refugee]	Legal Integration Total [nw allochtonen refugee]

Appendix B: Vensim Model Code

```
********************************************************
.Control
********************************************************~
Simulation Control Parameters
|
class : A,"B-F","G+I","H+J","K-L","M-N","R-U"
~
~ |
FINAL TIME = 2044
~ year
~ The final time for the simulation.
|
group : non refugee,refugee
~
~ |
i : D1,D2,D3,D4,D5,D6,D7,D8,D9,D10,D11,D12,D13,D14
~
~ |
INITIAL TIME = 2007
~ year
~ The initial time for the simulation.
|
k : D1,D2,D3,D4,D5,D6,D7,D8,D9,D10,D11,D12,D13,D14
~
~ |
non refugee : autochtonen,"w-allochtonen","nw-allochtonen"
~
~ |
"nw-allochtonen total" : "nw-allochtonen","nw-allochtonen refugee"
~
~ |
refugee : "w-allochtonen refugee","nw-allochtonen refugee"
~
~ |
SAVEPER = 1 / 12
~ year [0,?]
~ The frequency with which output is stored.
|
TIME STEP = 1 / 12
~ year [0,?]
~ The time step for the simulation.
|
type : single,multi
~
~ |
"w-allochtonen total" : "w-allochtonen","w-allochtonen refugee"
~
~ |
********************************************************
.Education
********************************************************~
|
Adult Education Initial[i] = 0.12, 0.08, 0.03, 0.08, 0.04, 0.12, 0.04, 0.03, 0.02, 0.04\
, 0.04, 0.02, 0.03, 0.02
~
~ |
"Arrive 14+"[i,group] = Youth Arrivals[i,group] * ( 4 / 14)
~
~ |
Arrive HAVO 1[i,group] = "Youth 14+ Arrivals"[i,group] * ( "VO2-HAVO1 Rate constant"[\
i,group] / "P8-VO1 rate constant"[group] ) * ( 1 / 4)
~~
28.5/94 for HAVO ratio. 1/3 to divide by 4 years
|
Arrive HAVO 2[i,group] = "Youth 14+ Arrivals"[i,group] * ( "VO2-HAVO1 Rate constant"[\
```

i,group] / "P8-VO1 rate constant"[group]) * (1 / 4)
~
~ |
Arrive HAVO 3[i,group] = "Youth 14+ Arrivals"[i,group] * ("VO2-HAVO1 Rate constant"[\
i,group] / "P8-VO1 rate constant"[group]) * (1 / 4)
~
~ |
Arrive Primary 1[i,group] = Youth Arrivals[i,group] * (1 / 14)
~~
1/14 to equally divide into all 14 years of mandatory education
|
Arrive Primary 2[i,group] = Youth Arrivals[i,group] * (1 / 14)
~~
1/14 to equally divide into all 14 years of mandatory education
|
Arrive Primary 3[i,group] = Youth Arrivals[i,group] * (1 / 14)
~~
1/14 to equally divide into all 14 years of mandatory education
|
Arrive Primary 4[i,group] = Youth Arrivals[i,group] * (1 / 14)
~~
1/14 to equally divide into all 14 years of mandatory education
|
Arrive Primary 5[i,group] = Youth Arrivals[i,group] * (1 / 14)
~~
1/14 to equally divide into all 14 years of mandatory education
|
Arrive Primary 6[i,group] = Youth Arrivals[i,group] * (1 / 14)
~~
1/14 to equally divide into all 14 years of mandatory education
|
Arrive Primary 7[i,group] = Youth Arrivals[i,group] * (1 / 14)
~~
1/14 to equally divide into all 14 years of mandatory education
|
Arrive Primary 8[i,group] = Youth Arrivals[i,group] * (1 / 14)
~~
1/14 to equally divide into all 14 years of mandatory education
|
"Arrive PRO/VSO"[i,group] = Youth Arrivals[i,group] * (2 / 14) * "P8-PRO/VSO1 Rate constant"\
[group]
~
~ |
Arrive VMBO 1[i,group] = "Youth 14+ Arrivals"[i,group] * ("VO2-VMBO1 Rate constant"[\
i,group] / "P8-VO1 rate constant"[group]) * (1 / 4)
~~
49/94 for VMBO ratio. 1/4 to divide by years
|
Arrive VMBO 2[i,group] = "Youth 14+ Arrivals"[i,group] * ("VO2-VMBO1 Rate constant"[\
i,group] / "P8-VO1 rate constant"[group]) * (1 / 4)
~
~ |
Arrive VO 1[i,group] = Youth Arrivals[i,group] * (1 / 14) * "P8-VO1 rate constant"[group\
]
~ Person/year
~ |
Arrive VO 2[i,group] = Youth Arrivals[i,group] * (1 / 14) * "P8-VO1 rate constant"[group\
]
~ Person/year
~ |
Arrive VWO 1[i,group] = "Youth 14+ Arrivals"[i,group] * ("VO2-VWO1 Rate constant"[i,\
group] / "P8-VO1 rate constant"[group]) * (1 / 4)
~~
15.5/94 is the VWO ratio. 1/4 divides it by 4 years
|
Arrive VWO 2[i,group] = "Youth 14+ Arrivals"[i,group] * ("VO2-VWO1 Rate constant"[i,\
group] / "P8-VO1 rate constant"[group]) * (1 / 4)
~

```
~ |
Arrive VWO 3[i,group] = "Youth 14+ Arrivals"[i,group] * ( "VO2-VWO1 Rate constant"[i,\
group] / "P8-VO1 rate constant"[group] ) * ( 1 / 4)
~
~ |
Arrive VWO 4[i,group] = "Youth 14+ Arrivals"[i,group] * ( "VO2-VWO1 Rate constant"[i,\
group] / "P8-VO1 rate constant"[group] ) * ( 1 / 4)
~
~ |
Births to Education[i,group] = Birthed Children[i,group] / 4 * PULSE TRAIN ( 0, 1 / 12\
, 1, FINAL TIME )
~ Person/year
~ /4 for four years until school begins
|
Education HI Class Ratio[class] = 0.00562, 0.21744, 0.23993, 0.13381, 0.07138, 0.24113\
, 0.09069
~
~ |
Education LI Class Ratio[autochtonen,class] = 0.00562, 0.21744, 0.23993, 0.13381, 0.07138\
, 0.24113, 0.09069 ~~|
Education LI Class Ratio["nw-allochtonen",class] = 0.001873, 0.1461, 0.240855, 0.13473\
, 0.14276, 0.24205, 0.09161 ~~|
Education LI Class Ratio["w-allochtonen",class] = 0.00562, 0.21744, 0.23993, 0.13381,\
0.07138, 0.24113, 0.09069 ~~|
Education LI Class Ratio["nw-allochtonen refugee",class] = 0.001873, 0.1461, 0.240855\
, 0.13473, 0.14276, 0.24205, 0.09161 ~~|
Education LI Class Ratio["w-allochtonen refugee",class] = 0.00562, 0.21744, 0.23993, \
0.13381, 0.07138, 0.24113, 0.09069
~
~ |
Education MI Class Ratio[class] = 0.00562, 0.21744, 0.23993, 0.13381, 0.07138, 0.24113\
, 0.09069
~
~ |
Education Population[i,group] = Primary Education[i,group] + VO[i,group] + "PRO/VSO"[\
i,group] + VMBO[i,group] + VWO[i,group] + HAVO[i,group] + "MBO-1"[i,group] + "MBO-2"\
[i,group] + "MBO-3"[i,group] + "MBO-4"[i,group] + HBO[i,group] + WO[i,group] + "PRO/VSO Graduates"\
[i,group] + VO Dropouts[i,group] + VMBO Graduates[i,group] + "VWO/HAVO Dropouts"[i,\
group] + "MBO-2 Dropouts"[i,group] + "MBO-3/4 Dropouts"[i,group] + "WO/HBO Dropouts"\
[i,group]
~
~ |
Education to HI[i,group] = INTEG( HBO to HI[i,group] + "MBO-4 to HI"[i,group] + WO to HI\
[i,group] - SUM ( Education to HI Rate[i,group,class!] ) , WO to HI[i,group] + HBO to HI\
[i,group] + "MBO-4 to HI"[i,group] )
~
~ |
Education to HI Rate[i,group,class] = Education to HI[i,group] * Education HI Class Ratio\
[class] * PULSE TRAIN ( 0, 1 / 12, 1, FINAL TIME )
~ Person/year
~ |
Education to LI[i,group] = INTEG( "MBO-1 to LI"[i,group] + "MBO-2 to LI"[i,group] + "PRO/VSO Graduate to LI"\
[i,group] + VMBO Graduate to LI[i,group] + VO to LI[i,group] + "VWO/HAVO to LI"[i,group\
] + "Youth 14+ to LI"[i,group] - SUM ( Education to LI Rate[i,group,class!] ) , 0)
~ Person
~ |
Education to LI Rate[i,group,class] = Education to LI[i,group] * Education LI Class Ratio\
[group,class] * PULSE TRAIN ( 0, 1 / 12, 1, FINAL TIME )
~ Person/year
~ |
Education to MI[i,group] = INTEG( "MBO-2 to MI"[i,group] + "MBO-3 to MI"[i,group] + "MBO-3/4 to MI"\
[i,group] + "WO/HBO to MI"[i,group] - SUM ( Education to MI Rate[i,group,class!] ) \
, "MBO-2 to MI"[i,group] + "MBO-3 to MI"[i,group] + "MBO-3/4 to MI"[i,group] + "WO/HBO to MI"\
[i,group] )
~ Person
~ |
Education to MI Rate[i,group,class] = Education to MI[i,group] * Education MI Class Ratio\
[class] * PULSE TRAIN ( 0, 1 / 12, 1, FINAL TIME )
```

~ Person/year
~ |
HAVO[i,group] = HAVO 1[i,group] + HAVO 2[i,group] + HAVO 3[i,group]
~
~ |
HAVO 1[i,group] = INTEG(Arrive HAVO 1[i,group] + "VO2-HAVO1"[i,group] - "HAVO1-HAVO2"\
[i,group] + IF THEN ELSE (HAVO 1[i,group] + (HAVO 1[i,group] * Working Population Net Zone Movement\
[i,group] * Youth Arrival Rate constant[group] / Mandatory Education Population[i,group\
]) <= 0, 0, (HAVO 1[i,group] * Working Population Net Zone Movement[i,group] * Youth Arrival Rate constant\
[group] / Mandatory Education Population[i,group])) , VO 2[i,group] * "VO2-HAVO1 Rate constant"\
[i,group])
~ Person
~ |
HAVO 2[i,group] = INTEG(Arrive HAVO 2[i,group] + "HAVO1-HAVO2"[i,group] - "HAVO2-HAVO3"\
[i,group] + IF THEN ELSE (HAVO 2[i,group] + (Working Population Net Zone Movement\
[i,group] * Youth Arrival Rate constant[group] * HAVO 2[i,group] / Mandatory Education Population\
[i,group]) <= 0, 0, (Working Population Net Zone Movement[i,group] * Youth Arrival Rate constant\
[group] * HAVO 2[i,group] / Mandatory Education Population[i,group])) , HAVO 1[i,\
group])
~ Person
~ |
HAVO 3[i,group] = INTEG(Arrive HAVO 3[i,group] + "HAVO2-HAVO3"[i,group] + "VMBO2-HAVO3"\
[i,group] - HAVO Dropout Rate[i,group] - "HAVO3-HBO1"[i,group] - "HAVO3-MBO-41"[i,group\
] + IF THEN ELSE (HAVO 3[i,group] + (Working Population Net Zone Movement[i,group\
] * Youth Arrival Rate constant[group] * HAVO 3[i,group] / Mandatory Education Population\
[i,group]) <= 0, 0, (Working Population Net Zone Movement[i,group] * Youth Arrival Rate constant\
[group] * HAVO 3[i,group] / Mandatory Education Population[i,group])) , HAVO 2[i,\
group] + VMBO 2[i,group] * "VMBO2-HAVO3 Rate constant"[i,group])
~ Person
~ |
HAVO Dropout Rate[i,group] = HAVO 3[i,group] * (HAVO Dropout Rate constant[i,group] \
/ HAVO3 Exit Rate constant[i,group]) * PULSE TRAIN (0, 1 / 12, 1, FINAL TIME)
~ Person/year
~ |
HAVO Dropout Rate constant[i,group] = 0.005 * Economic Integration HI district[i,group\
]
~
~ |
"HAVO1-HAVO2"[i,group] = HAVO 1[i,group] * PULSE TRAIN (0, 1 / 12, 1, FINAL TIME)
~ Person/year
~ |
"HAVO2-HAVO3"[i,group] = HAVO 2[i,group] * PULSE TRAIN (0, 1 / 12, 1, FINAL TIME)
~ Person/year
~ |
HAVO3 Exit Rate constant[i,group] = "VO2-HAVO1 Rate constant"[i,group] + "VMBO2-HAVO3 Rate constant"\
[i,group]
~
~ |
"HAVO3-HBO1 Rate constant"[i,group] = 0.27
~
~ |
"HAVO3-HBO1"[i,group] = HAVO 3[i,group] * ("HAVO3-HBO1 Rate constant"[i,group] / HAVO3 Exit Rate constant\
[i,group]) * PULSE TRAIN (0, 1 / 12, 1, FINAL TIME)
~ Person/year
~ |
"HAVO3-MBO-41 Rate constant"[group] = 0.04
~
~ |
"HAVO3-MBO-41"[i,group] = HAVO 3[i,group] * ("HAVO3-MBO-41 Rate constant"[group] / HAVO3 Exit Rate constant\
[i,group]) * PULSE TRAIN (0, 1 / 12, 1, FINAL TIME)
~ Person/year
~ |
HBO[i,group] = HBO 1[i,group] + HBO 2[i,group] + HBO 3[i,group] + HBO 4[i,group]
~
~ |
HBO 1[i,group] = INTEG("HAVO3-HBO1"[i,group] + "MBO-44-HBO1"[i,group] - "HBO1-HBO2"[\
i,group] - "HBO1-WO1"[i,group] , HAVO 3[i,group] * "HAVO3-HBO1 Rate constant"[i,group\
] + "MBO-4 4"[i,group] * "MBO-44-HBO1 Rate constant"[i,group] + Higher Education Population Initial\

[i,group] * ("HAVO3-HBO1 Rate constant"[i,group] / (90 * 4)))
~ Person
~ |
HBO 1 Exit Rate constant[i,group] = "HAVO3-HBO1 Rate constant"[i,group] + "MBO-44-HBO1 Rate constant"\
[i,group]
~
~ |
HBO 2[i,group] = INTEG("HBO1-HBO2"[i,group] - "HBO2-HBO3"[i,group] , HBO 1[i,group] \
)
~ Person
~ |
HBO 3[i,group] = INTEG("HBO2-HBO3"[i,group] - "HBO3-HBO4"[i,group] , HBO 2[i,group] \
)
~ Person
~ |
HBO 4[i,group] = INTEG("HBO3-HBO4"[i,group] - HBO Dropout Rate[i,group] - HBO to HI[\
i,group] , HBO 3[i,group])
~ Person
~ |
HBO Dropout Rate[i,group] = HBO 4[i,group] * (HBO Dropout Rate constant[group] / "HBO1-HBO2 Rate constant"\
[i,group]) * PULSE TRAIN (0, 1 / 12, 1, FINAL TIME)
~ Person/year
~ |
HBO Dropout Rate constant[group] = 0.16
~
~ |
HBO to HI[i,group] = HBO 4[i,group] * (HBO to HI Rate constant[group] / "HBO1-HBO2 Rate constant"\
[i,group]) * PULSE TRAIN (0, 1 / 12, 1, FINAL TIME)
~ Person/year
~ |
HBO to HI Rate constant[group] = 0.25
~
~ |
"HBO1-HBO2 Rate constant"[i,group] = HBO 1 Exit Rate constant[i,group] - "HBO1-WO1 Rate constant"\
[i,group]
~
~ |
"HBO1-HBO2"[i,group] = HBO 1[i,group] * ("HBO1-HBO2 Rate constant"[i,group] / HBO 1 Exit Rate constant\
[i,group]) * PULSE TRAIN (0, 1 / 12, 1, FINAL TIME)
~
~ |
"HBO1-WO1 Rate constant"[i,group] = 0.01
~
~ |
"HBO1-WO1"[i,group] = HBO 1[i,group] * ("HBO1-WO1 Rate constant"[i,group] / HBO 1 Exit Rate constant\
[i,group]) * PULSE TRAIN (0, 1 / 12, 1, FINAL TIME)
~ Person/year
~ |
"HBO2-HBO3"[i,group] = HBO 2[i,group] * PULSE TRAIN (0, 1 / 12, 1, FINAL TIME)
~
~ |
"HBO3-HBO4"[i,group] = HBO 3[i,group] * PULSE TRAIN (0, 1 / 12, 1, FINAL TIME)
~
~ |
Higher Education Population Initial[i,group] = SUM (Working Population[i,group,class\
!]) * Adult Education Initial[i]
~
~ |
Mandatory Education Population[i,group] = Primary Education[i,group] + "PRO/VSO"[i,group\
] + VO[i,group] + VWO[i,group] + HAVO[i,group] + VMBO[i,group] + VO Dropouts[i,group\
] + "PRO/VSO Graduates"[i,group] + "Youth 14+ Arrivals Not in Education"[i,group] +\
VMBO Graduates[i,group]
~
~ |
"MBO-1 1"[i,group] = INTEG("VMBO2-MBO-11"[i,group] - "MBO-1 to LI"[i,group] , VMBO 2\
[i,group] * "VMBO2-MBO-11 Rate constant"[group] + Higher Education Population Initial\
[i,group] * ("VMBO2-MBO-11 Rate constant"[group] / (90)))
~ Person

```
~ |
"MBO-1 to LI"[i,group] = "MBO-1 1"[i,group] * PULSE TRAIN ( 0, 1 / 12, 1, FINAL TIME \
)
~ Person/year
~ |
"MBO-1"[i,group] = "MBO-1 1"[i,group]
~
~ |
"MBO-2 1"[i,group] = INTEG( "VMBO2-MBO-21"[i,group] - "MBO-21-MBO-22"[i,group] , VMBO 2\
[i,group] * "VMBO2-MBO-21 Rate constant"[group] + Higher Education Population Initial\
[i,group] * ( "VMBO2-MBO-21 Rate constant"[group] / ( 90 * 3) ) )
~ Person
~ |
"MBO-2 2"[i,group] = INTEG( "MBO-21-MBO-22"[i,group] - "MBO-22-MBO-23"[i,group] , "MBO-2 1"\
[i,group] )
~ Person
~ |
"MBO-2 3"[i,group] = INTEG( "MBO-22-MBO-23"[i,group] - "MBO-2 Dropout Rate"[i,group] \
- "MBO-2 to MI"[i,group] , "MBO-2 2"[i,group] )
~ Person
~ |
"MBO-2 Dropout Rate constant"[group] = 0.03
~
~ |
"MBO-2 Dropout Rate"[i,group] = "MBO-2 3"[i,group] * ( "MBO-2 Dropout Rate constant"[\
group] / "VMBO2-MBO-21 Rate constant"[group] ) * PULSE TRAIN ( 0, 1 / 12, 1, FINAL TIME\
)
~ Person/year
~ |
"MBO-2 Dropouts"[i,group] = INTEG( "MBO-2 Dropout Rate"[i,group] - "MBO-2 to LI"[i,group\
] , "MBO-2 Dropout Rate"[i,group] )
~
~ |
"MBO-2 to LI"[i,group] = "MBO-2 Dropouts"[i,group] * PULSE TRAIN ( 0, 1 / 12, 1, FINAL TIME\
)
~ Person/year
~ |
"MBO-2 to MI Rate constant"[group] = 0.06
~
~ |
"MBO-2 to MI"[i,group] = "MBO-2 3"[i,group] * ( "MBO-2 to MI Rate constant"[group] / \
"VMBO2-MBO-21 Rate constant"[group] ) * PULSE TRAIN ( 0, 1 / 12, 1, FINAL TIME )
~ Person/year
~ |
"MBO-2"[i,group] = "MBO-2 1"[i,group] + "MBO-2 2"[i,group] + "MBO-2 3"[i,group]
~
~ |
"MBO-21-MBO-22"[i,group] = "MBO-2 1"[i,group] * PULSE TRAIN ( 0, 1 / 12, 1, FINAL TIME\
)
~ Person/year
~ |
"MBO-22-MBO-23"[i,group] = "MBO-2 2"[i,group] * PULSE TRAIN ( 0, 1 / 12, 1, FINAL TIME\
)
~ Person/year
~ |
"MBO-3 1"[i,group] = INTEG( "VMBO2-MBO-31"[i,group] - "MBO-31-MBO-32"[i,group] , VMBO 2\
[i,group] * "VMBO2-MBO-31 Rate constant"[group] + Higher Education Population Initial\
[i,group] * ( "VMBO2-MBO-31 Rate constant"[group] / ( 90 * 4) ) )
~ Person
~ |
"MBO-3 2"[i,group] = INTEG( "MBO-31-MBO-32"[i,group] - "MBO-32-MBO-33"[i,group] , "MBO-3 1"\
[i,group] )
~ Person
~ |
"MBO-3 3"[i,group] = INTEG( "MBO-32-MBO-33"[i,group] - "MBO-33-MBO-34"[i,group] , "MBO-3 2"\
[i,group] )
~ Person
~ |
```

```
"MBO-3 4"[i,group] = INTEG( "MBO-33-MBO-34"[i,group] - "MBO-3 Dropout Rate"[i,group] \
- "MBO-3 to MI"[i,group] , "MBO-3 3"[i,group] )
~ Person
~ |
"MBO-3 Dropout Rate constant"[group] = 0.02
~
~ |
"MBO-3 Dropout Rate"[i,group] = "MBO-3 4"[i,group] * ( "MBO-3 Dropout Rate constant"[\
group] / "VMBO2-MBO-31 Rate constant"[group] ) * PULSE TRAIN ( 0, 1 / 12, 1, FINAL TIME\
)
~ Person/year
~ |
"MBO-3 to MI Rate constant"[group] = 0.04
~
~ |
"MBO-3 to MI"[i,group] = "MBO-3 4"[i,group] * ( "MBO-3 to MI Rate constant"[group] / \
"VMBO2-MBO-31 Rate constant"[group] ) * PULSE TRAIN ( 0, 1 / 12, 1, FINAL TIME )
~ Person/year
~ |
"MBO-3"[i,group] = "MBO-3 1"[i,group] + "MBO-3 2"[i,group] + "MBO-3 3"[i,group] + "MBO-3 4"\
[i,group]
~
~ |
"MBO-3/4 Dropouts"[i,group] = INTEG( "MBO-3 Dropout Rate"[i,group] + "MBO-4 Dropout Rate"\
[i,group] - "MBO-3/4 to MI"[i,group] , "MBO-4 Dropout Rate"[i,group] + "MBO-3 Dropout Rate"\
[i,group] )
~
~ |
"MBO-3/4 to MI"[i,group] = "MBO-3/4 Dropouts"[i,group] * PULSE TRAIN ( 0, 1 / 12, 1, \
FINAL TIME )
~ Person/year
~ |
"MBO-31-MBO-32"[i,group] = "MBO-3 1"[i,group] * PULSE TRAIN ( 0, 1 / 12, 1, FINAL TIME\
)
~ Person/year
~ |
"MBO-32-MBO-33"[i,group] = "MBO-3 2"[i,group] * PULSE TRAIN ( 0, 1 / 12, 1, FINAL TIME\
)
~ Person/year
~ |
"MBO-33-MBO-34"[i,group] = "MBO-3 3"[i,group] * PULSE TRAIN ( 0, 1 / 12, 1, FINAL TIME\
)
~ Person/year
~ |
"MBO-4 1"[i,group] = INTEG( "HAVO3-MBO-41"[i,group] + "VMBO2-MBO-41"[i,group] - "MBO-41-MBO-42"\
[i,group] , VMBO 2[i,group] * "VMBO2-MBO-41 Rate constant"[group] + HAVO 3[i,group]\
* "HAVO3-MBO-41 Rate constant"[group] + Higher Education Population Initial[i,group\
] * ( ( "VMBO2-MBO-41 Rate constant"[group] + "HAVO3-MBO-41 Rate constant"[group] )\
/ ( 90 * 4) ) )
~ Person
~ |
"MBO-4 2"[i,group] = INTEG( "MBO-41-MBO-42"[i,group] - "MBO-42-MBO-43"[i,group] , "MBO-4 1"\
[i,group] )
~ Person
~ |
"MBO-4 3"[i,group] = INTEG( "MBO-42-MBO-43"[i,group] - "MBO-43-MBO-44"[i,group] , "MBO-4 2"\
[i,group] )
~ Person
~ |
"MBO-4 4 Exit Rate constant"[group] = "HAVO3-MBO-41 Rate constant"[group] + "VMBO2-MBO-41 Rate constant"\
[group]
~
~ |
"MBO-4 4"[i,group] = INTEG( "MBO-43-MBO-44"[i,group] - "MBO-4 Dropout Rate"[i,group] \
- "MBO-4 to HI"[i,group] - "MBO-44-HBO1"[i,group] , "MBO-4 3"[i,group] )
~ Person
~ |
"MBO-4 Dropout Rate constant"[group] = 0.05
```

~
~ |
"MBO-4 Dropout Rate"[i,group] = "MBO-4 4"[i,group] * ("MBO-4 Dropout Rate constant"[\
group] / "MBO-4 4 Exit Rate constant"[group]) * PULSE TRAIN (0, 1 / 12, 1, FINAL TIME\
)
~ Person/year
~ |
"MBO-4 to HI Rate constant"[group] = 0.12
~
~ |
"MBO-4 to HI"[i,group] = "MBO-4 4"[i,group] * ("MBO-4 to HI Rate constant"[group] / \
"MBO-4 4 Exit Rate constant"[group]) * PULSE TRAIN (0, 1 / 12, 1, FINAL TIME)
~ Person/year
~ |
"MBO-4"[i,group] = "MBO-4 1"[i,group] + "MBO-4 2"[i,group] + "MBO-4 3"[i,group] + "MBO-4 4"\
[i,group]
~
~ |
"MBO-41-MBO-42"[i,group] = "MBO-4 1"[i,group] * PULSE TRAIN (0, 1 / 12, 1, FINAL TIME\
)
~ Person/year
~ |
"MBO-42-MBO-43"[i,group] = "MBO-4 2"[i,group] * PULSE TRAIN (0, 1 / 12, 1, FINAL TIME\
)
~ Person/year
~ |
"MBO-43-MBO-44"[i,group] = "MBO-4 3"[i,group] * PULSE TRAIN (0, 1 / 12, 1, FINAL TIME\
)
~ Person/year
~ |
"MBO-44-HBO1 Rate constant"[i,group] = 0.15
~
~ |
"MBO-44-HBO1"[i,group] = "MBO-4 4"[i,group] * ("MBO-44-HBO1 Rate constant"[i,group] \
/ "MBO-4 4 Exit Rate constant"[group]) * PULSE TRAIN (0, 1 / 12, 1, FINAL TIME)
~ Person/year
~ |
"P/V1-P/V2"[i,group] = "PRO/VSO 1"[i,group] * PULSE TRAIN (0, 1 / 12, 1, FINAL TIME \
)
~ Person/year
~ |
"P/V2-P/V3"[i,group] = "PRO/VSO 2"[i,group] * PULSE TRAIN (0, 1 / 12, 1, FINAL TIME \
)
~ Person/year
~ |
"P/V3-P/V4"[i,group] = "PRO/VSO 3"[i,group] * PULSE TRAIN (0, 1 / 12, 1, FINAL TIME \
)
~ Person/year
~ |
"P1-P2"[i,group] = Primary 1[i,group] * PULSE TRAIN (0, 1 / 12, 1, FINAL TIME)
~ Person/year
~ |
"P2-P3"[i,group] = Primary 2[i,group] * PULSE TRAIN (0, 1 / 12, 1, FINAL TIME)
~ Person/year
~ |
"P3-P4"[i,group] = Primary 3[i,group] * PULSE TRAIN (0, 1 / 12, 1, FINAL TIME)
~ Person/year
~ |
"P4-P5"[i,group] = Primary 4[i,group] * PULSE TRAIN (0, 1 / 12, 1, FINAL TIME)
~ Person/year
~ |
"P5-P6"[i,group] = Primary 5[i,group] * PULSE TRAIN (0, 1 / 12, 1, FINAL TIME)
~ Person/year
~ |
"P6-P7"[i,group] = Primary 6[i,group] * PULSE TRAIN (0, 1 / 12, 1, FINAL TIME)
~ Person/year
~ |
"P7-P8"[i,group] = Primary 7[i,group] * PULSE TRAIN (0, 1 / 12, 1, FINAL TIME)

```
~ Person/year
~ |
"P8-PRO/VSO1 Rate constant"[group] = 0.06
~ Fraction/year
~ |
"P8-PRO/VSO1"[i,group] = Primary 8[i,group] * "P8-PRO/VSO1 Rate constant"[group] * PULSE TRAIN\
( 0, 1 / 12, 1, FINAL TIME )
~ Person/year
~ |
"P8-VO1 rate constant"[group] = 0.94
~
~ |
"P8-VO1"[i,group] = Primary 8[i,group] * "P8-VO1 rate constant"[group] * PULSE TRAIN \
( 0, 1 / 12, 1, FINAL TIME )
~ Person/year
~ |
Primary 1[i,group] = INTEG( Arrive Primary 1[i,group] + Births to Education[i,group] \
- "P1-P2"[i,group] + IF THEN ELSE ( Primary 1[i,group] + ( Working Population Net Zone Movement\
[i,group] * Youth Arrival Rate constant[group] * Primary 1[i,group] / Mandatory Education Population\
[i,group] ) <= 0, 0, ( Working Population Net Zone Movement[i,group] * Youth Arrival Rate constant\
[group] * Primary 1[i,group] / Mandatory Education Population[i,group] ) ) , Youth Education Initial\
[i,group] )
~ Person
~ |
Primary 2[i,group] = INTEG( Arrive Primary 2[i,group] + "P1-P2"[i,group] - "P2-P3"[i,\
group] + IF THEN ELSE ( Primary 2[i,group] + ( Working Population Net Zone Movement\
[i,group] * Youth Arrival Rate constant[group] * Primary 2[i,group] / Mandatory Education Population\
[i,group] ) <= 0, 0, ( Working Population Net Zone Movement[i,group] * Youth Arrival Rate constant\
[group] * Primary 2[i,group] / Mandatory Education Population[i,group] ) ) , Youth Education Initial\
[i,group] )
~ Person
~ |
Primary 3[i,group] = INTEG( Arrive Primary 3[i,group] + "P2-P3"[i,group] - "P3-P4"[i,\
group] + IF THEN ELSE ( Primary 3[i,group] + ( Working Population Net Zone Movement\
[i,group] * Youth Arrival Rate constant[group] * Primary 3[i,group] / Mandatory Education Population\
[i,group] ) <= 0, 0, ( Working Population Net Zone Movement[i,group] * Youth Arrival Rate constant\
[group] * Primary 3[i,group] / Mandatory Education Population[i,group] ) ) , Youth Education Initial\
[i,group] )
~ Person
~ |
Primary 4[i,group] = INTEG( Arrive Primary 4[i,group] + "P3-P4"[i,group] - "P4-P5"[i,\
group] + IF THEN ELSE ( Primary 4[i,group] + ( Working Population Net Zone Movement\
[i,group] * Youth Arrival Rate constant[group] * Primary 4[i,group] / Mandatory Education Population\
[i,group] ) <= 0, 0, ( Working Population Net Zone Movement[i,group] * Youth Arrival Rate constant\
[group] * Primary 4[i,group] / Mandatory Education Population[i,group] ) ) , Youth Education Initial\
[i,group] )
~ Person
~ |
Primary 5[i,group] = INTEG( Arrive Primary 5[i,group] + "P4-P5"[i,group] - "P5-P6"[i,\
group] + IF THEN ELSE ( Primary 5[i,group] + ( Working Population Net Zone Movement\
[i,group] * Youth Arrival Rate constant[group] * Primary 5[i,group] / Mandatory Education Population\
[i,group] ) <= 0, 0, ( Working Population Net Zone Movement[i,group] * Youth Arrival Rate constant\
[group] * Primary 5[i,group] / Mandatory Education Population[i,group] ) ) , Youth Education Initial\
[i,group] )
~ Person
~ |
Primary 6[i,group] = INTEG( Arrive Primary 6[i,group] + "P5-P6"[i,group] - "P6-P7"[i,\
group] + IF THEN ELSE ( Primary 6[i,group] + ( Working Population Net Zone Movement\
[i,group] * Youth Arrival Rate constant[group] * Primary 6[i,group] / Mandatory Education Population\
[i,group] ) <= 0, 0, ( Working Population Net Zone Movement[i,group] * Youth Arrival Rate constant\
[group] * Primary 6[i,group] / Mandatory Education Population[i,group] ) ) , Youth Education Initial\
[i,group] )
~ Person
~ |
Primary 7[i,group] = INTEG( Arrive Primary 7[i,group] + "P6-P7"[i,group] - "P7-P8"[i,\
group] + IF THEN ELSE ( Primary 7[i,group] + ( Working Population Net Zone Movement\
[i,group] * Youth Arrival Rate constant[group] * Primary 7[i,group] / Mandatory Education Population\
[i,group] ) <= 0, 0, ( Working Population Net Zone Movement[i,group] * Youth Arrival Rate constant\
```

```
[group] * Primary 7[i,group] / Mandatory Education Population[i,group] ) ) , Youth Education Initial\
[i,group] )
~ Person
~ |
Primary 8[i,group] = INTEG( Arrive Primary 8[i,group] + "P7-P8"[i,group] - "P8-PRO/VSO1"\
[i,group] - "P8-VO1"[i,group] + IF THEN ELSE ( Primary 8[i,group] + ( Working Population Net Zone Movement\
[i,group] * Youth Arrival Rate constant[group] * Primary 8[i,group] / Mandatory Education Population\
[i,group] ) <= 0, 0, ( Working Population Net Zone Movement[i,group] * Youth Arrival Rate constant\
[group] * Primary 8[i,group] / Mandatory Education Population[i,group] ) ) , Youth Education Initial\
[i,group] )
~ Person
~ |
Primary Education[i,group] = Primary 1[i,group] + Primary 2[i,group] + Primary 3[i,group\
] + Primary 4[i,group] + Primary 5[i,group] + Primary 6[i,group] + Primary 7[i,group\
] + Primary 8[i,group]
~
~ |
"PRO/VSO 1"[i,group] = INTEG( "Arrive PRO/VSO"[i,group] + "P8-PRO/VSO1"[i,group] - "P/V1-P/V2"\
[i,group] + IF THEN ELSE ( "PRO/VSO 1"[i,group] + ( Working Population Net Zone Movement\
[i,group] * Youth Arrival Rate constant[group] * "PRO/VSO 1"[i,group] / Mandatory Education Population\
[i,group] ) <= 0, 0, ( Working Population Net Zone Movement[i,group] * Youth Arrival Rate constant\
[group] * "PRO/VSO 1"[i,group] / Mandatory Education Population[i,group] ) ) , Youth Education Initial\
[i,group] * "P8-PRO/VSO1 Rate constant"[group] )
~ Person
~ |
"PRO/VSO 2"[i,group] = INTEG( "Arrive PRO/VSO"[i,group] + "P/V1-P/V2"[i,group] - "P/V2-P/V3"\
[i,group] + IF THEN ELSE ( "PRO/VSO 2"[i,group] + ( Working Population Net Zone Movement\
[i,group] * Youth Arrival Rate constant[group] * "PRO/VSO 2"[i,group] / Mandatory Education Population\
[i,group] ) <= 0, 0, ( Working Population Net Zone Movement[i,group] * Youth Arrival Rate constant\
[group] * "PRO/VSO 2"[i,group] / Mandatory Education Population[i,group] ) ) , "PRO/VSO 1"\
[i,group] )
~ Person
~ |
"PRO/VSO 3"[i,group] = INTEG( "Arrive PRO/VSO"[i,group] + "P/V2-P/V3"[i,group] - "P/V3-P/V4"\
[i,group] + IF THEN ELSE ( "PRO/VSO 3"[i,group] + ( Working Population Net Zone Movement\
[i,group] * Youth Arrival Rate constant[group] * "PRO/VSO 3"[i,group] / Mandatory Education Population\
[i,group] ) <= 0, 0, ( Working Population Net Zone Movement[i,group] * Youth Arrival Rate constant\
[group] * "PRO/VSO 3"[i,group] / Mandatory Education Population[i,group] ) ) , "PRO/VSO 2"\
[i,group] )
~ Person
~ |
"PRO/VSO 4"[i,group] = INTEG( "Arrive PRO/VSO"[i,group] + "P/V3-P/V4"[i,group] - "PRO/VSO to Graduate"\
[i,group] + IF THEN ELSE ( "PRO/VSO 4"[i,group] + ( Working Population Net Zone Movement\
[i,group] * Youth Arrival Rate constant[group] * "PRO/VSO 4"[i,group] / Mandatory Education Population\
[i,group] ) <= 0, 0, ( Working Population Net Zone Movement[i,group] * Youth Arrival Rate constant\
[group] * "PRO/VSO 4"[i,group] / Mandatory Education Population[i,group] ) ) , "PRO/VSO 3"\
[i,group] )
~ Person
~ |
"PRO/VSO Graduate to LI"[i,group] = "PRO/VSO Graduates"[i,group] / 2 * PULSE TRAIN ( \
0, 1 / 12, 1, FINAL TIME )
~ Person/year
~ Divided by 2 to account for two years to get to 18
|
"PRO/VSO Graduates"[i,group] = INTEG( "PRO/VSO to Graduate"[i,group] - "PRO/VSO Graduate to LI"\
[i,group] + IF THEN ELSE ( "PRO/VSO Graduates"[i,group] + ( Working Population Net Zone Movement\
[i,group] * Youth Arrival Rate constant[group] * "PRO/VSO Graduates"[i,group] / Mandatory Education Population\
[i,group] ) <= 0, 0, ( Working Population Net Zone Movement[i,group] * Youth Arrival Rate constant\
[group] * "PRO/VSO Graduates"[i,group] / Mandatory Education Population[i,group] ) \
) , "PRO/VSO 4"[i,group] * 2)
~
~ |
"PRO/VSO to Graduate"[i,group] = "PRO/VSO 4"[i,group] * PULSE TRAIN ( 0, 1 / 12, 1, FINAL TIME\
)
~ Person/year
~ |
"PRO/VSO"[i,group] = "PRO/VSO 1"[i,group] + "PRO/VSO 2"[i,group] + "PRO/VSO 3"[i,group\
] + "PRO/VSO 4"[i,group]
```

~
~ |
"VBMO1-VMBO2"[i,group] = VMBO 1[i,group]
~
~ |
VMBO[i,group] = VMBO 1[i,group] + VMBO 2[i,group]
~
~ |
VMBO 1[i,group] = INTEG(Arrive VMBO 1[i,group] + "VO2-VMBO1"[i,group] - "VBMO1-VMBO2"\
[i,group] + IF THEN ELSE (VMBO 1[i,group] + (Working Population Net Zone Movement\
[i,group] * Youth Arrival Rate constant[group] * VMBO 1[i,group] / Mandatory Education Population\
[i,group]) <= 0, 0, (Working Population Net Zone Movement[i,group] * Youth Arrival Rate constant\
[group] * VMBO 1[i,group] / Mandatory Education Population[i,group])) , VO 2[i,group\
] * "VO2-VMBO1 Rate constant"[i,group])
~ Person
~ |
VMBO 2[i,group] = INTEG(Arrive VMBO 2[i,group] + "VBMO1-VMBO2"[i,group] - VMBO 2 to Graduate\
[i,group] - "VMBO2-HAVO3"[i,group] - "VMBO2-MBO-11"[i,group] - "VMBO2-MBO-21"[i,group\
] - "VMBO2-MBO-31"[i,group] - "VMBO2-MBO-41"[i,group] + IF THEN ELSE (VMBO 2[i,group\
] + (Working Population Net Zone Movement[i,group] * Youth Arrival Rate constant[group\
] * VMBO 2[i,group] / Mandatory Education Population[i,group]) <= 0, 0, (Working Population Net Zone Movement\
[i,group] * Youth Arrival Rate constant[group] * VMBO 2[i,group] / Mandatory Education Population\
[i,group])) , VMBO 1[i,group])
~ Person
~ |
VMBO 2 to Graduate[i,group] = VMBO 2[i,group] * (VMBO 2 to Graduate Rate constant[i,\
group] / "VO2-VMBO1 Rate constant"[i,group]) * PULSE TRAIN (0, 1 / 12, 1, FINAL TIME\
)
~ Person/year
~ |
VMBO 2 to Graduate Rate constant[i,group] = 0.02 * Economic Integration LI district[i\
,group]
~~
Contains both qualified (0.01) and unqualified (0.01) leavers of education \
system
|
VMBO Graduate to LI[i,group] = VMBO Graduates[i,group] / 2 * PULSE TRAIN (0, 1 / 12,\
1, FINAL TIME)
~ Person/year
~ Divided by 2 to account for 2 years to get to 18
|
VMBO Graduates[i,group] = INTEG(VMBO 2 to Graduate[i,group] - VMBO Graduate to LI[i,\
group] + IF THEN ELSE (VMBO Graduates[i,group] + (Working Population Net Zone Movement\
[i,group] * Youth Arrival Rate constant[group] * VMBO Graduates[i,group] / Mandatory Education Population\
[i,group]) <= 0, 0, (Working Population Net Zone Movement[i,group] * Youth Arrival Rate constant\
[group] * VMBO Graduates[i,group] / Mandatory Education Population[i,group])) , VMBO 2 to Graduate Rate constant\
[i,group] * 2)
~
~ |
"VMBO2-HAVO3 Rate constant"[i,group] = 0.03
~
~ |
"VMBO2-HAVO3"[i,group] = VMBO 2[i,group] * ("VMBO2-HAVO3 Rate constant"[i,group] / "VO2-VMBO1 Rate constant"\
[i,group]) * PULSE TRAIN (0, 1 / 12, 1, FINAL TIME)
~
~ |
"VMBO2-MBO-11 Rate constant"[group] = 0.01
~
~ |
"VMBO2-MBO-11"[i,group] = VMBO 2[i,group] * ("VMBO2-MBO-11 Rate constant"[group] / "VO2-VMBO1 Rate constant"\
[i,group]) * PULSE TRAIN (0, 1 / 12, 1, FINAL TIME)
~ Person/year
~ |
"VMBO2-MBO-21 Rate constant"[group] = 0.09
~
~ |
"VMBO2-MBO-21"[i,group] = VMBO 2[i,group] * ("VMBO2-MBO-21 Rate constant"[group] / "VO2-VMBO1 Rate constant"\
[i,group]) * PULSE TRAIN (0, 1 / 12, 1, FINAL TIME)

```
~ Person/year
~ |
"VMBO2-MBO-31 Rate constant"[group] = 0.06
~
~ |
"VMBO2-MBO-31"[i,group] = VMBO 2[i,group] * ( "VMBO2-MBO-31 Rate constant"[group] / "VO2-VMBO1 Rate constant"\
[i,group] ) * PULSE TRAIN ( 0, 1 / 12, 1, FINAL TIME )
~ Person/year
~ |
"VMBO2-MBO-41 Rate constant"[group] = 0.28
~
~ |
"VMBO2-MBO-41"[i,group] = VMBO 2[i,group] * ( "VMBO2-MBO-41 Rate constant"[group] / "VO2-VMBO1 Rate constant"\
[i,group] ) * PULSE TRAIN ( 0, 1 / 12, 1, FINAL TIME )
~ Person/year
~ |
VO[i,group] = VO 1[i,group] + VO 2[i,group]
~
~ |
VO 1[i,group] = INTEG( Arrive VO 1[i,group] + "P8-VO1"[i,group] - "VO1-VO2"[i,group] \
+ IF THEN ELSE ( VO 1[i,group] + ( Working Population Net Zone Movement[i,group] * \
Youth Arrival Rate constant[group] * VO 1[i,group] / Mandatory Education Population\
[i,group] ) <= 0, 0, ( Working Population Net Zone Movement[i,group] * Youth Arrival Rate constant\
[group] * VO 1[i,group] / Mandatory Education Population[i,group] ) ) , Youth Education Initial\
[i,group] * "P8-VO1 rate constant"[group] )
~ Person
~ |
VO 2[i,group] = INTEG( Arrive VO 2[i,group] + "VO1-VO2"[i,group] - VO Dropout Rate[i,\
group] - "VO2-HAVO1"[i,group] - "VO2-VMBO1"[i,group] - "VO2-VWO1"[i,group] + IF THEN ELSE\
( VO 2[i,group] + ( Working Population Net Zone Movement[i,group] * Youth Arrival Rate constant\
[group] * VO 2[i,group] / Mandatory Education Population[i,group] ) <= 0, 0, ( Working Population Net Zone Movement\
[i,group] * Youth Arrival Rate constant[group] * VO 2[i,group] / Mandatory Education Population\
[i,group] ) ) , VO 1[i,group] )
~ Person
~ |
VO Dropout Rate[i,group] = VO 2[i,group] * ( VO Dropout Rate constant[i,group] / VO Exit Rate Constant\
[i,group] ) * PULSE TRAIN ( 0, 1 / 12, 1, FINAL TIME )
~ Person/year
~ |
VO Dropout Rate constant[i,group] = 0.01 * Economic Integration LI district[i,group]
~
~ |
VO Dropouts[i,group] = INTEG( VO Dropout Rate[i,group] - VO to LI[i,group] + IF THEN ELSE\
( VO Dropouts[i,group] + ( Working Population Net Zone Movement[i,group] * Youth Arrival Rate constant\
[group] * VO Dropouts[i,group] / Mandatory Education Population[i,group] ) <= 0, 0,\
( Working Population Net Zone Movement[i,group] * Youth Arrival Rate constant[group\
] * VO Dropouts[i,group] / Mandatory Education Population[i,group] ) ) , VO Dropout Rate\
[i,group] * 4)
~
~ |
VO Exit Rate Constant[i,group] = "VO2-HAVO1 Rate constant"[i,group] + "VO2-VMBO1 Rate constant"\
[i,group] + "VO2-VWO1 Rate constant"[i,group] + VO Dropout Rate constant[i,group]
~
~ |
VO to LI[i,group] = VO Dropouts[i,group] / 4 * PULSE TRAIN ( 0, 1 / 12, 1, FINAL TIME\
)
~ Person/year
~ Divided by 4 to account for 4 years to get to 18
|
"VO1-VO2"[i,group] = VO 1[i,group] * PULSE TRAIN ( 0, 1 / 12, 1, FINAL TIME )
~ Person/year
~ |
"VO2-HAVO1 Rate constant"[i,group] = 0.285 * Economic Integration HI district[i,group\
]
~
~ |
"VO2-HAVO1"[i,group] = VO 2[i,group] * ( "VO2-HAVO1 Rate constant"[i,group] / VO Exit Rate Constant\
[i,group] ) * PULSE TRAIN ( 0, 1 / 12, 1, FINAL TIME )
```

~ Person/year
~ |
"VO2-VMBO1 Rate constant"[i,group] = 0.49 * Economic Integration LI district[i,group]
~
~ |
"VO2-VMBO1"[i,group] = VO 2[i,group] * ("VO2-VMBO1 Rate constant"[i,group] / VO Exit Rate Constant\
[i,group]) * PULSE TRAIN (0, 1 / 12, 1, FINAL TIME)
~ Person/year
~ |
"VO2-VWO1 Rate constant"[i,group] = 0.155 * Economic Integration HI district[i,group]
~
~ |
"VO2-VWO1"[i,group] = VO 2[i,group] * ("VO2-VWO1 Rate constant"[i,group] / VO Exit Rate Constant\
[i,group]) * PULSE TRAIN (0, 1 / 12, 1, FINAL TIME)
~ Person/year
~ |
VWO[i,group] = VWO 1[i,group] + VWO 2[i,group] + VWO 3[i,group] + VWO 4[i,group]
~
~ |
VWO 1[i,group] = INTEG(Arrive VWO 1[i,group] + "VO2-VWO1"[i,group] - "VWO1-VWO2"[i,group\
] + IF THEN ELSE (VWO 1[i,group] + (Working Population Net Zone Movement[i,group]\
* Youth Arrival Rate constant[group] * VWO 1[i,group] / Mandatory Education Population\
[i,group]) <= 0, 0, (Working Population Net Zone Movement[i,group] * Youth Arrival Rate constant\
[group] * VWO 1[i,group] / Mandatory Education Population[i,group])) , VO 2[i,group\
] * "VO2-VWO1 Rate constant"[i,group])
~ Person
~ |
VWO 2[i,group] = INTEG(Arrive VWO 2[i,group] + "VWO1-VWO2"[i,group] - "VWO2-VWO3"[i,\
group] + IF THEN ELSE (VWO 2[i,group] + (Working Population Net Zone Movement[i,group\
] * Youth Arrival Rate constant[group] * VWO 2[i,group] / Mandatory Education Population\
[i,group]) <= 0, 0, (Working Population Net Zone Movement[i,group] * Youth Arrival Rate constant\
[group] * VWO 2[i,group] / Mandatory Education Population[i,group])) , VWO 1[i,group\
])
~ Person
~ |
VWO 3[i,group] = INTEG(Arrive VWO 3[i,group] + "VWO2-VWO3"[i,group] - "VWO3-VWO4"[i,\
group] + IF THEN ELSE (VWO 3[i,group] + (Working Population Net Zone Movement[i,group\
] * Youth Arrival Rate constant[group] * VWO 3[i,group] / Mandatory Education Population\
[i,group]) <= 0, 0, (Working Population Net Zone Movement[i,group] * Youth Arrival Rate constant\
[group] * VWO 3[i,group] / Mandatory Education Population[i,group])) , VWO 2[i,group\
])
~ Person
~ |
VWO 4[i,group] = INTEG(Arrive VWO 4[i,group] + "VWO3-VWO4"[i,group] - VWO Dropout Rate\
[i,group] - "VWO4-WO1"[i,group] + IF THEN ELSE (VWO 4[i,group] + (Working Population Net Zone Movement\
[i,group] * Youth Arrival Rate constant[group] * VWO 4[i,group] / Mandatory Education Population\
[i,group]) <= 0, 0, (Working Population Net Zone Movement[i,group] * Youth Arrival Rate constant\
[group] * VWO 4[i,group] / Mandatory Education Population[i,group])) , VWO 3[i,group\
])
~ Person
~ |
VWO Dropout Rate[i,group] = VWO 4[i,group] * (VWO Dropout Rate Constant[i,group] / "VO2-VWO1 Rate constant"\
[i,group]) * PULSE TRAIN (0, 1 / 12, 1, FINAL TIME)
~ Person/year
~ |
VWO Dropout Rate Constant[i,group] = 0.005 * Economic Integration HI district[i,group\
]
~
~ |
"VWO/HAVO Dropouts"[i,group] = INTEG(HAVO Dropout Rate[i,group] + VWO Dropout Rate[i\
,group] - "VWO/HAVO to LI"[i,group] , VWO Dropout Rate[i,group] + HAVO Dropout Rate\
[i,group])
~
~ |
"VWO/HAVO to LI"[i,group] = "VWO/HAVO Dropouts"[i,group] * PULSE TRAIN (0, 1 / 12, 1\
, FINAL TIME)
~ Person/year
~ |

```
"VWO1-VWO2"[i,group] = VWO 1[i,group] * PULSE TRAIN ( 0, 1 / 12, 1, FINAL TIME )
~ Person/year
~ |
"VWO2-VWO3"[i,group] = VWO 2[i,group] * PULSE TRAIN ( 0, 1 / 12, 1, FINAL TIME )
~ Person/year
~ |
"VWO3-VWO4"[i,group] = VWO 3[i,group] * PULSE TRAIN ( 0, 1 / 12, 1, FINAL TIME )
~ Person/year
~ |
"VWO4-WO1 Rate constant"[i,group] = 0.15 * Economic Integration HI district[i,group]
~
~ |
"VWO4-WO1"[i,group] = VWO 4[i,group] * ( "VWO4-WO1 Rate constant"[i,group] / "VO2-VWO1 Rate constant"\
[i,group] ) * PULSE TRAIN ( 0, 1 / 12, 1, FINAL TIME )
~ Person/year
~ |
WO[i,group] = WO 1[i,group] + WO 2[i,group] + WO 3[i,group]
~
~ |
WO 1[i,group] = INTEG( "HBO1-WO1"[i,group] + "VWO4-WO1"[i,group] - "WO1-WO2"[i,group]\
, VWO 4[i,group] * "VWO4-WO1 Rate constant"[i,group] + HBO 1[i,group] * "HBO1-WO1 Rate constant"\
[i,group] + Higher Education Population Initial[i,group] * ( ( "VWO4-WO1 Rate constant"\
[i,group] + "HBO1-WO1 Rate constant"[i,group] ) / ( 90 * 3) ) )
~ Person
~ 90 is the sum of all rates into Higher Education (HO)
|
WO 2[i,group] = INTEG( "WO1-WO2"[i,group] - "WO2-WO3"[i,group] , WO 1[i,group] )
~ Person
~ |
WO 3[i,group] = INTEG( "WO2-WO3"[i,group] - WO Dropout Rate[i,group] - WO to HI[i,group\
] , WO 2[i,group] )
~ Person
~ |
WO Dropout Rate[i,group] = WO 3[i,group] * ( WO Dropout Rate constant[group] / WO3 Exit Rate constant\
[i,group] ) * PULSE TRAIN ( 0, 1 / 12, 1, FINAL TIME )
~ Person/year
~ |
WO Dropout Rate constant[group] = 0.04
~
~ |
WO to HI[i,group] = WO 3[i,group] * ( WO to HI Rate constant[group] / WO3 Exit Rate constant\
[i,group] ) * PULSE TRAIN ( 0, 1 / 12, 1, FINAL TIME )
~ Person/year
~ |
WO to HI Rate constant[group] = 0.12
~
~ |
"WO/HBO Dropouts"[i,group] = INTEG( HBO Dropout Rate[i,group] + WO Dropout Rate[i,group\
] - "WO/HBO to MI"[i,group] , WO Dropout Rate[i,group] + HBO Dropout Rate[i,group] \
)
~
~ |
"WO/HBO to MI"[i,group] = "WO/HBO Dropouts"[i,group] * PULSE TRAIN ( 0, 1 / 12, 1, FINAL TIME\
)
~ Person/year
~ |
"WO1-WO2"[i,group] = WO 1[i,group] * PULSE TRAIN ( 0, 1 / 12, 1, FINAL TIME )
~ Person/year
~ |
"WO2-WO3"[i,group] = WO 2[i,group] * PULSE TRAIN ( 0, 1 / 12, 1, FINAL TIME )
~ Person/year
~ |
WO3 Exit Rate constant[i,group] = "HBO1-WO1 Rate constant"[i,group] + "VWO4-WO1 Rate constant"\
[i,group]
~
~ |
Working Population Net Zone Movement[i,group] = ( SUM ( LNZM LI net zone movement[i,group\
,class!] + MNZM MI net zone movement[i,group,class!] + HNZM HI net zone movement[i,\
```

```
group,class!] ) - ( Exam Failure Exit Rate[i,group] + SUM ( LD LI departures[i,group\
,class!] + MD MI departures[i,group,class!] + HD HI departures[i,group,class!] ) ) \
)
~
~ |
"Youth 14+ Arrivals Not in Education"[i,group] = INTEG( "Youth 14+ to Work"[i,group] \
- "Youth 14+ to LI"[i,group] + IF THEN ELSE ( "Youth 14+ Arrivals Not in Education"\
[i,group] + ( Working Population Net Zone Movement[i,group] * Youth Arrival Rate constant\
[group] * "Youth 14+ Arrivals Not in Education"[i,group] / Mandatory Education Population\
[i,group] ) <= 0, 0, ( Working Population Net Zone Movement[i,group] * Youth Arrival Rate constant\
[group] * "Youth 14+ Arrivals Not in Education"[i,group] / Mandatory Education Population\
[i,group] ) ) , "Youth 14+ to Work"[i,group] * 2)
~
~ |
"Youth 14+ Arrivals"[i,group] = INTEG( "Arrive 14+"[i,group] - Arrive HAVO 1[i,group]\
- Arrive HAVO 2[i,group] - Arrive HAVO 3[i,group] - Arrive VMBO 1[i,group] - Arrive VMBO 2\
[i,group] - Arrive VWO 1[i,group] - Arrive VWO 2[i,group] - Arrive VWO 3[i,group] -\
Arrive VWO 4[i,group] - "Youth 14+ to Work"[i,group] , "Arrive 14+"[i,group] )
~ Person
~ |
"Youth 14+ to LI Rate constant"[i,group] = VO Dropout Rate constant[i,group] + "VO2-HAVO1 Rate constant"\
[i,group] + "VO2-VMBO1 Rate constant"[i,group]
~
~ |
"Youth 14+ to LI"[i,group] = "Youth 14+ Arrivals Not in Education"[i,group] / 4 * PULSE TRAIN\
( 0, 1 / 12, 1, FINAL TIME )
~ Person/year
~ Denominator is a weighted average of the proportion of those who would go \
to HAVO so have to wait one year. And then those who would go to VMBO but \
have to wait either one or two years to enter the workforce. Or dropouts \
who have to wait 1, 2 , 3 or 4 years.
|
"Youth 14+ to Work"[i,group] = "Youth 14+ Arrivals"[i,group] * ( ( "VO2-HAVO1 Rate constant"\
[i,group] / "P8-VO1 rate constant"[group] ) * ( 1 / 4) + ( "VO2-VMBO1 Rate constant"\
[i,group] / "P8-VO1 rate constant"[group] ) * ( 2 / 4) + ( VO Dropout Rate constant\
[i,group] / "P8-VO1 rate constant"[group] ) )
~~
These are those who are too old to go (or cannot get) into HAVO or VMBO \
but cannot get into VWO. So they go to U
|
Youth Arrivals[i,group] = INTEG( Youth Arrival Rate[i,group] - "Arrive 14+"[i,group] \
- Arrive Primary 1[i,group] - Arrive Primary 2[i,group] - Arrive Primary 3[i,group]\
- Arrive Primary 4[i,group] - Arrive Primary 5[i,group] - Arrive Primary 6[i,group\
] - Arrive Primary 7[i,group] - Arrive Primary 8[i,group] - "Arrive PRO/VSO"[i,group\
] - Arrive VO 1[i,group] - Arrive VO 2[i,group] , Youth Arrival Rate[i,group] )
~
~ |
Youth Education Initial[i,autochtonen] = 104.16, 270.86, 122.32, 267.7, 391.6, 266.27\
, 338.68, 417.39, 51.58, 722.8, 359.21, 307.93, 89, 127.77 ~~|
Youth Education Initial[i,"w-allochtonen"] = 31.87, 93.37, 16.18, 57.72, 57.41, 60.27\
, 75.24, 62.59, 4.25, 100.35, 68.76, 35.69, 6.92, 15.39 ~~|
Youth Education Initial[i,"nw-allochtonen"] = 76.18, 567.15, 41.19, 198.55, 72.77, 175.04\
, 524.44, 214.68, 4.83, 179.88, 334.75, 102.18, 2.95, 10.73 ~~|
Youth Education Initial[i,"w-allochtonen refugee"] = 0.01, 0.03, 0.01, 0.02, 0.02, 0.02\
, 0.03, 0.02, 0.01, 0.03, 0.02, 0.01, 0.01, 0.01 ~~|
Youth Education Initial[i,"nw-allochtonen refugee"] = 0.35, 2.58, 0.19, 0.9, 0.33, 0.8\
, 2.39, 0.98, 0.02, 0.82, 1.53, 0.47, 0.01, 0.05
~
~ |
********************************************************
.Government
********************************************************~
|
AV Assessed value = HAVT Housing assessed value total + BAVAT Business assessed value area total\
+ IAVT Income Assessed Value Total
~ thousand euros
~ |
BAV Business assessed value[i] = SUM ( Business Establishments i[i,class!] ) * Business Assessed Value
```

~ thousand euros
~ |
BAVAT Business assessed value area total = SUM (BAV Business assessed value[i!])
~ thousand euros
~ |
Business Assessed Value = 300
~ thousand euros/productive unit
~ |
CTRNP Change in TRNP = (TRN Tax ratio needed - TRNP Tax ratio needed perceived) / TRNPT Tax ratio needed perception time
~ Dmnl/year
~ |
ELC Enterprise location decision i[i,A] = 1 ~~|
ELC Enterprise location decision i[i,"B-F"] = 1 ~~|
ELC Enterprise location decision i[i,"G+I"] = 1 ~~|
ELC Enterprise location decision i[i,"H+J"] = 1 ~~|
ELC Enterprise location decision i[i,"K-L"] = 1 ~~|
ELC Enterprise location decision i[i,"M-N"] = 1 ~~|
ELC Enterprise location decision i[i,"R-U"] = 1
~
~ |
ETM Enterprise tax multiplier = WITH LOOKUP((1.44 * LN (TR Tax ratio)) , ([(-2,0\
)-(4,2)],(-2,1.3),(-1,1.2),(0,1),(1,0.8),(2,0.5),(3,0.25),(4,0.1)))
~
~ |
HATM HI arrival tax multiplier = WITH LOOKUP((1.44 * LN (TR Tax ratio)) , ([(-2,\
0)-(4,2)],(-2,1.4),(0,1),(2,0.7),(4,0.3)))
~
~ |
HAV Housing assessed value[i] = SUM (HH HI housing i[i,type!]) * HHAV HI housing assessed value\
+ SUM (LH LI housing i[i,type!]) * LHAV LI housing assessed value + SUM (MH MI housing i\
[i,type!]) * MHAV MI housing assessed value
~ thousand euros
~ |
HAVT Housing assessed value total = SUM (HAV Housing assessed value[i!])
~ thousand euros
~ |
HHAV HI housing assessed value = 1.5
~ thousand euros/housing unit
~ |
HHCP HI housing construction program i[i,type] = HH HI housing i[i,type] * HHCR HI housing construction rate\
[i] * HHLM HI housing land multiplier i[i] * IF THEN ELSE (Time > SWT1 Switch time\
, 1, 0)
~
~ |
HHCR HI housing construction rate[i] = 0
~ Fraction/year
~ |
HHTM HI housing tax multiplier = WITH LOOKUP((1.44 * LN (TR Tax ratio)) , ([(-2,\
0)-(4,1.5)],(-2,1.2),(0,1),(2,0.7),(4,0.3)))
~
~ |
IAVT Income Assessed Value Total = Taxes Received HI + Taxes Recieved MI + Taxes Recieved LI
~ thousand euros
~ |
Language Program Rate[group] = 0
~
~ |
LEM LI educational multiplier = WITH LOOKUP(TPCR Tax per capita ratio , ([(0,0)-(3,2\
)],(0,0.2),(0.5,0.7),(1,1),(1.5,1.3),(2,1.5),(2.5,1.6),(3,1.7)))
~
~ |
LHCR LI housing construction rate[i] = 0
~ housing units/man/year
~ |
LHDP LI housing demolition program i[i,type] = LH LI housing i[i,type] * LHDR LI housing demolition rate
~ housing units/year
~ |
LHDR LI housing demolition rate = 0

~ Fraction/year
~ |
LHP LI housing program[i,type] = HUT Housing units total i[i,type] * LHCR LI housing construction rate\
[i] * MHLM MI housing land multiplier i[i] * IF THEN ELSE (Time > SWT1 Switch time\
, 1, 0)
~ housing units/year
~ |
LHPM LI housing program multiplier = WITH LOOKUP(LHPR LI housing program rate , ([(0\
,0)-(0.05,3)],(0,1),(0.01,1.2),(0.02,1.5),(0.03,1.9),(0.04,2.4),(0.05,3)))
~
~ |
LHPR LI housing program rate = SUM (LHP LI housing program[i!,type!]) / SUM (LC LI class\
[class!])
~ housing units/(year*man)
~ |
LJP LI job program i[i,class] = LJPR LI Job Program Rate
~
~ |
LJPR LI Job Program Rate = 0
~
~ |
LTP LI training program[i,group,class] = LI Low Income[i,group,class] * LTR LI training rate\
[group] * IF THEN ELSE (Time > SWT1 Switch time , 1, 0)
~ Person/year
~ |
LTR LI training rate[group] = 0
~ Fraction/year
~ |
MATM MI arrival tax multiplier = WITH LOOKUP((1.44 * LN (TR Tax ratio)) , ([(-2,\
0)-(4,2)],(-2,1.2),(0,1),(2,0.7),(4,0.3)))
~
~ |
MEM MI educational multiplier = WITH LOOKUP(TPCR Tax per capita ratio , ([(0,0)-(3,2\
)],(0,0.2),(0.5,0.7),(1,1),(1.5,1.3),(2,1.5),(2.5,1.6),(3,1.7)))
~ Dmnl
~ |
MHAV MI housing assessed value = 1
~ thousand euros/housing unit
~ |
MHCP MI housing construction program i[i,type] = HUT Housing units total i[i,type] * \
MHCR MI housing construction rate[i] * MHLM MI housing land multiplier i[i] * IF THEN ELSE\
(Time > SWT1 Switch time , 1, 0)
~
~ |
MHCR MI housing construction rate[i] = 0
~ Fraction/year
~ |
MHTM MI housing tax multiplier = WITH LOOKUP((1.44 * LN (TR Tax ratio)) , ([(-2,\
0)-(4,2)],(-2,1.2),(0,1),(2,0.7),(4,0.3)))
~
~ |
MTP MI training program[i,group,class] = MI Middle Income[i,group,class] * MTR MI training rate\
[group] * IF THEN ELSE (Time > SWT1 Switch time , 1, 0)
~
~ |
MTR MI training rate[group] = 0
~ Fraction/year
~ |
PEM Public expenditure multiplier = WITH LOOKUP(TPCR Tax per capita ratio , ([(0,0)-\
(3,4)],(0,0.2),(0.5,0.6),(1,1),(1.5,1.6),(2,2.4),(2.5,3.2),(3,4)))
~
~ |
Policy 1 applied to zone i[i] = 0
~
~ |
SWT1 Switch time = 2015
~ year
~ |

TAI Tax assessment indicated = TNT Tax needed total / AV Assessed value
~ Fraction/year
~ |
TAN Tax assessment normal = 100
~ Fraction/year
~ |
Tax Amount HI = 19.53
~ thousand euros/Person
~ |
Tax Amount LI = 0.571
~ thousand euros/Person
~ |
Tax Amount MI = 2.71
~ thousand euros/Person
~ |
Tax Per Capita = 14
~ thousand euros/(Person*year)
~ |
Taxes Received HI = SUM (HI High Income[i!,group!,class!]) * Tax Amount HI
~ thousand euros
~ |
Taxes Recieved LI = SUM (LI Low Income[i!,group!,class!]) * Tax Amount LI
~ thousand euros
~ |
Taxes Recieved MI = SUM (MI Middle Income[i!,group!,class!]) * Tax Amount MI
~ thousand euros
~ |
TC Tax collections = AV Assessed value * TR Tax ratio
~ thousand euros/year
~ |
TCM Tax collection multiplier = WITH LOOKUP("MLRT MI/LI ratio total" , ([(0,0)-(3,2)\
],(0,2),(0.5,1.6),(1,1.3),(1.5,1.1),(2,1),(2.5,0.9),(3,0.8)))
~
~ |
TN Tax needed i[i] = PT Population Total * Tax Per Capita * TCM Tax collection multiplier
~ thousand euros/year
~ |
TNT Tax needed total = SUM (TN Tax needed i[i!])
~ thousand euros/year
~ |
TPCN Tax per capita normal = 14
~ thousand euros/year
~ |
TPCR Tax per capita ratio = ((TC Tax collections / PT Population Total) + TPCSP Tax per capita subsidy program\
) / TPCN Tax per capita normal
~
~ |
TPCS Tax per capita subsidy = 0
~
~ |
TPCSP Tax per capita subsidy program = TPCS Tax per capita subsidy
~ dollars/(year*Person)
~ |
TR Tax ratio = WITH LOOKUP((1.44 * LN (TRNP Tax ratio needed perceived)) , ([(-2\
,0)-(4,4)],(-2,0.3),(-1,0.5),(0,1),(1,1.8),(2,2.8),(3,3.6),(4,4)))
~ d
~ |
TRN Tax ratio needed = TAI Tax assessment indicated / TAN Tax assessment normal
~ Dmnl
~ |
TRNP Tax ratio needed perceived = INTEG(CTRNP Change in TRNP , TRN Tax ratio needed \
)
~
~ |
TRNPT Tax ratio needed perception time = 30
~
~ |
****

.Job Market
**~
|
AAAHJAZ Average accessibility attractiveness to HI jobs all zones[class] = SUM ((HJ HI jobs k\
[k!,class] / HCD HI Class District[i!,class]) / TDF Trip distribution function i[i\
!,k!]) / 14
~
~ |
AAALJAZ Average accessibility attractiveness to LI jobs all zones[class] = SUM ((LJ LI jobs k\
[k!,class] / LCD LI Class District[i!,class]) / TDF Trip distribution function i[i\
!,k!]) / 14
~
~ |
AAAMJAZ Average accessibility attractiveness to MI jobs all zones[class] = SUM ((MJ MI jobs k\
[k!,class] / MCD MI Class District[i!,class]) / TDF Trip distribution function i[i\
!,k!]) / 14
~
~ |
AAHJZ Accessibility attractiveness to HI jobs zone i[i,class] = SUM ((HJ HI jobs k[\
k!,class] / HCD HI Class District[i!,class]) / TDF Trip distribution function i[i,\
k!])
~
~ |
AALJZ Accessibility attractiveness to LI jobs zone i[i,class] = SUM ((LJ LI jobs k[\
k!,class] / LCD LI Class District[i!,class]) / TDF Trip distribution function i[i,\
k!])
~
~ |
AAMJZ Accessibility attractiveness to MI jobs zone i[i,class] = SUM ((MJ MI jobs k[\
k!,class] / MCD MI Class District[i!,class]) / TDF Trip distribution function i[i,\
k!])
~
~ |
AIMHM Attractiveness for internal migration HI multiplier i[i,class] = (1 / Economic Tension HI i compared to average\
[i]) * HLAM HI locational attractiveness multiplier i[i,class] * HAPM HI arrival population multiplier i\
[i] * HAHM HI arrival housing multiplier i[i]
~
~ |
AIMHM Attractiveness for internal migration HI multiplier k[D1,class] = AIMHM Attractiveness for internal migration HI multiplier i\
[D1,class] ~~|
AIMHM Attractiveness for internal migration HI multiplier k[D2,class] = AIMHM Attractiveness for internal migration HI multiplier i\
[D2,class] ~~|
AIMHM Attractiveness for internal migration HI multiplier k[D3,class] = AIMHM Attractiveness for internal migration HI multiplier i\
[D3,class] ~~|
AIMHM Attractiveness for internal migration HI multiplier k[D4,class] = AIMHM Attractiveness for internal migration HI multiplier i\
[D4,class] ~~|
AIMHM Attractiveness for internal migration HI multiplier k[D5,class] = AIMHM Attractiveness for internal migration HI multiplier i\
[D5,class] ~~|
AIMHM Attractiveness for internal migration HI multiplier k[D6,class] = AIMHM Attractiveness for internal migration HI multiplier i\
[D6,class] ~~|
AIMHM Attractiveness for internal migration HI multiplier k[D7,class] = AIMHM Attractiveness for internal migration HI multiplier i\
[D7,class] ~~|
AIMHM Attractiveness for internal migration HI multiplier k[D8,class] = AIMHM Attractiveness for internal migration HI multiplier i\
[D8,class] ~~|
AIMHM Attractiveness for internal migration HI multiplier k[D9,class] = AIMHM Attractiveness for internal migration HI multiplier i\
[D9,class] ~~|
AIMHM Attractiveness for internal migration HI multiplier k[D10,class] = AIMHM Attractiveness for internal migration HI multiplier i\
[D10,class] ~~|

AIMHM Attractiveness for internal migration HI multiplier k[D11,class] = AIMHM Attractiveness for internal migration HI multiplier i\
[D11,class] ~~|
AIMHM Attractiveness for internal migration HI multiplier k[D12,class] = AIMHM Attractiveness for internal migration HI multiplier i\
[D12,class] ~~|
AIMHM Attractiveness for internal migration HI multiplier k[D13,class] = AIMHM Attractiveness for internal migration HI multiplier i\
[D13,class] ~~|
AIMHM Attractiveness for internal migration HI multiplier k[D14,class] = AIMHM Attractiveness for internal migration HI multiplier i\
[D14,class]
~
~ |
AIMHMP Attractiveness for internal migration HI multiplier perceived k[k,class] = INTEG\
(CAIMHMP Change in AIMHMP[k,class] , AIMHM Attractiveness for internal migration HI multiplier k\
[k,class])
~
~ |
AIMHMPT Attractiveness for internal migration HI multiplier perception time k = 5
~
~ |
AIMLM Attractiveness for internal migration LI multiplier i[i,class] = "LHM LI/housing multiplier i"\
[i] * LLAM LI locational attractiveness multiplier i[i,class] * (1 / Economic Tension LI i compared to average\
[i])
~
~ |
AIMLM Attractiveness for internal migration LI multiplier k[D1,class] = AIMLM Attractiveness for internal migration LI multiplier i\
[D1,class] ~~|
AIMLM Attractiveness for internal migration LI multiplier k[D2,class] = AIMLM Attractiveness for internal migration LI multiplier i\
[D2,class] ~~|
AIMLM Attractiveness for internal migration LI multiplier k[D3,class] = AIMLM Attractiveness for internal migration LI multiplier i\
[D3,class] ~~|
AIMLM Attractiveness for internal migration LI multiplier k[D4,class] = AIMLM Attractiveness for internal migration LI multiplier i\
[D4,class] ~~|
AIMLM Attractiveness for internal migration LI multiplier k[D5,class] = AIMLM Attractiveness for internal migration LI multiplier i\
[D5,class] ~~|
AIMLM Attractiveness for internal migration LI multiplier k[D6,class] = AIMLM Attractiveness for internal migration LI multiplier i\
[D6,class] ~~|
AIMLM Attractiveness for internal migration LI multiplier k[D7,class] = AIMLM Attractiveness for internal migration LI multiplier i\
[D7,class] ~~|
AIMLM Attractiveness for internal migration LI multiplier k[D8,class] = AIMLM Attractiveness for internal migration LI multiplier i\
[D8,class] ~~|
AIMLM Attractiveness for internal migration LI multiplier k[D9,class] = AIMLM Attractiveness for internal migration LI multiplier i\
[D9,class] ~~|
AIMLM Attractiveness for internal migration LI multiplier k[D10,class] = AIMLM Attractiveness for internal migration LI multiplier i\
[D10,class] ~~|
AIMLM Attractiveness for internal migration LI multiplier k[D11,class] = AIMLM Attractiveness for internal migration LI multiplier i\
[D11,class] ~~|
AIMLM Attractiveness for internal migration LI multiplier k[D12,class] = AIMLM Attractiveness for internal migration LI multiplier i\
[D12,class] ~~|
AIMLM Attractiveness for internal migration LI multiplier k[D13,class] = AIMLM Attractiveness for internal migration LI multiplier i\
[D13,class] ~~|
AIMLM Attractiveness for internal migration LI multiplier k[D14,class] = AIMLM Attractiveness for internal migration LI multiplier i\

[D14,class]
~
~ |
AIMLMP Attractiveness for internal migration LI multiplier perceived k[k,class] = INTEG\
(CAIMLMP Change in AIMLMP[k,class] , AIMLM Attractiveness for internal migration LI multiplier k\
[k,class])
~
~ |
AIMLMPT Attractiveness for internal migration LI multiplier perception time k = 5
~
~ |
AIMMM Attractiveness for internal migration MI multiplier i[i,class] = MLAM MI locational attractiveness multiplier i\
[i,class] * MALM MI arrival LI multiplier i[i] * MAHM MI arrival housing multiplier i\
[i] * (1 / Economic Tension MI i compared to average[i])
~
~ |
AIMMM Attractiveness for internal migration MI multiplier k[D1,class] = AIMMM Attractiveness for internal migration MI multiplier i\
[D1,class] ~~|
AIMMM Attractiveness for internal migration MI multiplier k[D2,class] = AIMMM Attractiveness for internal migration MI multiplier i\
[D2,class] ~~|
AIMMM Attractiveness for internal migration MI multiplier k[D3,class] = AIMMM Attractiveness for internal migration MI multiplier i\
[D3,class] ~~|
AIMMM Attractiveness for internal migration MI multiplier k[D4,class] = AIMMM Attractiveness for internal migration MI multiplier i\
[D4,class] ~~|
AIMMM Attractiveness for internal migration MI multiplier k[D5,class] = AIMMM Attractiveness for internal migration MI multiplier i\
[D5,class] ~~|
AIMMM Attractiveness for internal migration MI multiplier k[D6,class] = AIMMM Attractiveness for internal migration MI multiplier i\
[D6,class] ~~|
AIMMM Attractiveness for internal migration MI multiplier k[D7,class] = AIMMM Attractiveness for internal migration MI multiplier i\
[D7,class] ~~|
AIMMM Attractiveness for internal migration MI multiplier k[D8,class] = AIMMM Attractiveness for internal migration MI multiplier i\
[D8,class] ~~|
AIMMM Attractiveness for internal migration MI multiplier k[D9,class] = AIMMM Attractiveness for internal migration MI multiplier i\
[D9,class] ~~|
AIMMM Attractiveness for internal migration MI multiplier k[D10,class] = AIMMM Attractiveness for internal migration MI multiplier i\
[D10,class] ~~|
AIMMM Attractiveness for internal migration MI multiplier k[D11,class] = AIMMM Attractiveness for internal migration MI multiplier i\
[D11,class] ~~|
AIMMM Attractiveness for internal migration MI multiplier k[D12,class] = AIMMM Attractiveness for internal migration MI multiplier i\
[D12,class] ~~|
AIMMM Attractiveness for internal migration MI multiplier k[D13,class] = AIMMM Attractiveness for internal migration MI multiplier i\
[D13,class] ~~|
AIMMM Attractiveness for internal migration MI multiplier k[D14,class] = AIMMM Attractiveness for internal migration MI multiplier i\
[D14,class]
~
~ |
AIMMMP Attractiveness for internal migration MI multiplier perceived k[i,class] = INTEG\
(CAIMMMP Change in AIMMMP[i,class] , AIMMM Attractiveness for internal migration MI multiplier k\
[i,class])
~
~ |
AIMMMPT Attractiveness for internal migration MI multiplier perception time k = 5
~
~ |

AMM Attractiveness for migration multiplier[i,class] = LAMM LI arrivals mobility multiplier\
* "LHM LI/housing multiplier" * PEM Public expenditure multiplier * "LJM LI/job multiplier"\
[i,class] * LHPM LI housing program multiplier
~ Dmnl
~ |
AMMP Attractiveness for migration multiplier perceived[i,class] = INTEG(CAMMP Change in AMMP\
[i,class] , 1)
~ Dmnl
~ |
AMMPT Attractiveness for migration multiplier perception time = 20
~ year
~ |
BHC Business HI class[class] = 0.8, 3.2, 1.7, 2.7, 1.5, 3.3, 1.6
~ persons/productive unit
~ |
BLC Business LI class[class] = 2.7, 11, 5.9, 9.2, 5.1, 8, 5.4
~
~ |
BMC Business MI class[class] = 1.9, 7.8, 4.2, 6.5, 3.6, 5.6, 3.8
~ persons/productive unit
~ double the calculated values (LI, MI, HI)
|
CAIMHMP Change in AIMHMP[k,class] = (AIMHM Attractiveness for internal migration HI multiplier k\
[k,class] - AIMHMP Attractiveness for internal migration HI multiplier perceived k[\
k,class]) / AIMHMPT Attractiveness for internal migration HI multiplier perception time k
~
~ |
CAIMLMP Change in AIMLMP[k,class] = (AIMLM Attractiveness for internal migration LI multiplier k\
[k,class] - AIMLMP Attractiveness for internal migration LI multiplier perceived k[\
k,class]) / AIMLMPT Attractiveness for internal migration LI multiplier perception time k
~
~ |
CAIMMMP Change in AIMMMP[k,class] = (AIMMM Attractiveness for internal migration MI multiplier k\
[k,class] - AIMMMP Attractiveness for internal migration MI multiplier perceived k[\
k,class]) / AIMMMPT Attractiveness for internal migration MI multiplier perception time k
~
~ |
CAMMP Change in AMMP[i,class] = (AMM Attractiveness for migration multiplier[i,class\
] - AMMP Attractiveness for migration multiplier perceived[i,class]) / AMMPT Attractiveness for migration multiplier perception time
~ Dmnl/year
~ |
CHAMP Change in HAMP[i,class] = (HAM HI arrival multiplier[i,class] - HAMP HI arrival multiplier perceived\
[i,class]) / HAMPT HI arrival multiplier perception time
~ Dmnl/year
~ |
Class Initial[i,A] = 0.00063, 0.0037, 0.00627, 0.00175, 0.00134, 0.00062, 0.00391, 0.00181\
, 1e-005, 0.00087, 0.00645, 0.00144, 0.0457, 0.00415 ~~|
Class Initial[i,"B-F"] = 0.07938, 0.16111, 0.25689, 0.14161, 0.14638, 0.12748, 0.2137\
, 0.2988, 0.35507, 0.19554, 0.27864, 0.2808, 0.23992, 0.26882 ~~|
Class Initial[i,"G+I"] = 0.262, 0.20605, 0.22777, 0.22836, 0.2079, 0.20492, 0.27958, \
0.24367, 0.20158, 0.221, 0.25949, 0.27005, 0.29134, 0.25526 ~~|
Class Initial[i,"H+J"] = 0.12893, 0.15281, 0.14644, 0.13449, 0.11175, 0.12873, 0.13052\
, 0.16255, 0.12618, 0.14476, 0.15047, 0.14923, 0.08206, 0.12444 ~~|
Class Initial[i,"K-L"] = 0.09249, 0.04085, 0.08324, 0.04754, 0.12528, 0.0959, 0.04177\
, 0.05156, 0.06548, 0.0879, 0.03719, 0.04997, 0.1156, 0.06458 ~~|
Class Initial[i,"M-N"] = 0.35953, 0.30128, 0.20904, 0.303, 0.32253, 0.32566, 0.2396, \
0.16788, 0.17592, 0.27551, 0.17483, 0.17451, 0.16344, 0.18313 ~~|
Class Initial[i,"R-U"] = 0.07704, 0.1342, 0.07034, 0.14325, 0.08482, 0.11669, 0.09091\
, 0.07374, 0.07576, 0.07441, 0.09293, 0.074, 0.06194, 0.09962
~
~ |
CLMMP Change in LMMP[i,class] = (LMM LI mobility multiplier[i,class] - LMMP LI mobility multiplier perceived\
[i,class]) / LMMPT LI mobility multiplier perception time
~ Dmnl/year
~ |
CLTMP Change in LTMP[i,group,class] = (LTM LI to MI[i,group,class] - LTMP LI to MI perceived\
[i,group,class]) / LTMPT LI to MI perception time

~ Dmnl/year
~ |
CMAMP Change in MAMP[i,class] = (MAM MI arrival multiplier[i,class] - MAMP MI arrival multiplier perceived\
[i,class]) / MAMPT MI arrival multiplier perception time
~ Dmnl
~ |
CMMMP Change in MMMP i[i,class] = (MMM MI mobility multiplier i[i,class] - MMMP MI mobility multiplier perceived i\
[i,class]) / MMMPT MI mobility multiplier perception time
~ Dmnl/year
~ |
CMRTP Change in MRTP = (SUM (MI Middle Income[i!,group!,class!]) / SUM (MJ MI jobs i\
[i!,class!]) - "MRTP MI/job ratio total perceived") / "MRPT MI/job ratio perception time"
~ Dmnl
~ |
Construction ratio total = WITH LOOKUP("Worker/Job ratio class"["B-F"] , ([(0,0)-(2.5\
,2)],(0,0.001),(0.5,0.5),(1,0.9),(1.5,1.1),(2,1.15),(2.5,1.2)))
~
~ |
HA HI arrivals[i,group,class] = HI High Income[i,group,class] * WPAN Working Population Arrivals normal\
[group] * HAMP HI arrival multiplier perceived[i,class]
~ Person/year
~ |
HAF HI arrival factor = 1
~ Dmnl
~ |
HAJM HI arrival job multiplier[i,class] = WITH LOOKUP("HJR HI/job ratio"[i,class] , \
([(0,0)-(2,3)],(0,2.7),(0.25,2.6),(0.5,2.4),(0.75,2),(1.05,1),(1.25,0.5),(1.5,0.2),\
(1.75,0.1),(2,0.05)))
~ Dmnl
~ |
HAM HI arrival multiplier[i,class] = HAJM HI arrival job multiplier[i,class] * HAPM HI arrival population multiplier\
[i] * HATM HI arrival tax multiplier * HAHM HI arrival housing multiplier[i] * HAF HI arrival factor
~ Dmnl
~ |
HAMP HI arrival multiplier perceived[i,class] = INTEG(CHAMP Change in HAMP[i,class] \
, 1)
~ Dmnl
~ |
HAMPT HI arrival multiplier perception time = 10
~ year
~ |
HAPM HI arrival population multiplier[i] = WITH LOOKUP("HPR HI/population ratio i"[i\
] , ([(0,0)-(0.1,2)],(0,0.3),(0.02,0.7),(0.04,1),(0.06,1.2),(0.08,1.3),(0.1,1.3)) \
)
~
~ |
HAPM HI arrival population multiplier i[i] = WITH LOOKUP("HPR HI/population ratio i"\
[i] , ([(0,0)-(0.5,2)],(0,0.3),(0.1,0.7),(0.2,1),(0.3,1.2),(0.4,1.3),(0.5,1.3)))
~ Dmnl
~ |
HC HI class[class] = SUM (HCD HI Class District[i!,class])
~
~ |
HCD HI Class District[i,class] = SUM (HI High Income[i,group!,class])
~
~ |
HCZA HI comparison zone i to average[i,class] = AAHJZ Accessibility attractiveness to HI jobs zone i\
[i,class] / AAAHJAZ Average accessibility attractiveness to HI jobs all zones[class\
]
~
~ |
HD HI departures[i,group,class] = HI High Income[i,group,class] * WPDN Working Population departures normal\
[group] * HDM HI departure multiplier[i,class]
~ Person/year
~ |
HDM HI departure multiplier[i,class] = WITH LOOKUP((1.44 * LN (HAM HI arrival multiplier\
[i,class])) , ([(-3,0)-(4,8)],(-3,8),(-2,4),(-1,2),(0,1),(1,0.5),(2,0.25),(3,0.125\
),(4,0.1)))

```
~
~ |
HI HI initial[i,autochtonen] = 2231.1, 1293.3, 1168.8, 2336.1, 6993, 3434.9, 1617.1, \
3067.8, 526.4, 10093.9, 1473.2, 2553.5, 1412.2, 1659.7 ~~|
HI HI initial[i,"w-allochtonen"] = 682.8, 445.8, 154.6, 503.7, 1025.3, 777.5, 359.2, \
460, 43.3, 1401.5, 282, 295.9, 109.8, 199.9 ~~|
HI HI initial[i,"nw-allochtonen"] = 1631.8, 2708, 393.5, 1732.7, 1299.5, 2258.1, 2504.1\
, 1577.9, 49.3, 2512, 1372.9, 847.2, 46.9, 139.3 ~~|
HI HI initial[i,"w-allochtonen refugee"] = 1e-005 ~~|
HI HI initial[i,"nw-allochtonen refugee"] = 1e-005
~
~ |
HI High Income[i,group,class] = INTEG( HA HI arrivals[i,group,class] + MTH MI to HI[i\
,group,class] - HD HI departures[i,group,class] + HNZM HI net zone movement[i,group\
,class] + Education to HI Rate[i,group,class] - HTM HI to MI[i,group,class] - ( HI High Income\
[i,group,class] * Exam Failure Exit Rate[i,group] / SUM ( Working Population[i,group\
,class!] ) ) + ( Immigrant Arrival Rate[i,group] * Immigrant HI Constant[group] * Education HI Class Ratio\
[class] ) + ( Refugee Arrival Rate[i,group] * Refugee HI Constant[group] * Education HI Class Ratio\
[class] ) , HI HI initial[i,group] * ( 1 - Adult Education Initial[i] ) * ( HJ HI jobs i\
[i,class] / SUM ( HJ HI jobs i[i,class!] ) ) )
~
~ |
HI High Income k[D1,group,class] = HI High Income[D1,group,class] ~~|
HI High Income k[D2,group,class] = HI High Income[D2,group,class] ~~|
HI High Income k[D3,group,class] = HI High Income[D3,group,class] ~~|
HI High Income k[D4,group,class] = HI High Income[D4,group,class] ~~|
HI High Income k[D5,group,class] = HI High Income[D5,group,class] ~~|
HI High Income k[D6,group,class] = HI High Income[D6,group,class] ~~|
HI High Income k[D7,group,class] = HI High Income[D7,group,class] ~~|
HI High Income k[D8,group,class] = HI High Income[D8,group,class] ~~|
HI High Income k[D9,group,class] = HI High Income[D9,group,class] ~~|
HI High Income k[D10,group,class] = HI High Income[D10,group,class] ~~|
HI High Income k[D11,group,class] = HI High Income[D11,group,class] ~~|
HI High Income k[D12,group,class] = HI High Income[D12,group,class] ~~|
HI High Income k[D13,group,class] = HI High Income[D13,group,class] ~~|
HI High Income k[D14,group,class] = HI High Income[D14,group,class]
~
~ |
HIBZM HI internal between zones movement i k[i,k,group,class] = "WPIOMN Working Population internal out-of-zone movement normal"\
* ( ( ( HI High Income[i,group,class] / ( AIMHM Attractiveness for internal migration HI multiplier i\
[i,class] * Cognitive Dissonance Multiplier[i,group] ) ) * ( HI High Income k[k,group\
,class] * AIMHMP Attractiveness for internal migration HI multiplier perceived k[k,\
class] ) ) / HC HI class[class] )
~
~ |
"HIIM HI internal into-zone movement"[D1,group,class] = SUM ( HIBZM HI internal between zones movement i k\
[i!,D1,group,class] ) ~~|
"HIIM HI internal into-zone movement"[D2,group,class] = SUM ( HIBZM HI internal between zones movement i k\
[i!,D2,group,class] ) ~~|
"HIIM HI internal into-zone movement"[D3,group,class] = SUM ( HIBZM HI internal between zones movement i k\
[i!,D3,group,class] ) ~~|
"HIIM HI internal into-zone movement"[D4,group,class] = SUM ( HIBZM HI internal between zones movement i k\
[i!,D4,group,class] ) ~~|
"HIIM HI internal into-zone movement"[D5,group,class] = SUM ( HIBZM HI internal between zones movement i k\
[i!,D5,group,class] ) ~~|
"HIIM HI internal into-zone movement"[D6,group,class] = SUM ( HIBZM HI internal between zones movement i k\
[i!,D6,group,class] ) ~~|
"HIIM HI internal into-zone movement"[D7,group,class] = SUM ( HIBZM HI internal between zones movement i k\
[i!,D7,group,class] ) ~~|
"HIIM HI internal into-zone movement"[D8,group,class] = SUM ( HIBZM HI internal between zones movement i k\
[i!,D8,group,class] ) ~~|
"HIIM HI internal into-zone movement"[D9,group,class] = SUM ( HIBZM HI internal between zones movement i k\
[i!,D9,group,class] ) ~~|
"HIIM HI internal into-zone movement"[D10,group,class] = SUM ( HIBZM HI internal between zones movement i k\
[i!,D10,group,class] ) ~~|
"HIIM HI internal into-zone movement"[D11,group,class] = SUM ( HIBZM HI internal between zones movement i k\
[i!,D11,group,class] ) ~~|
```

```
"HIIM HI internal into-zone movement"[D12,group,class] = SUM ( HIBZM HI internal between zones movement i k\
[i!,D12,group,class] ) ~~|
"HIIM HI internal into-zone movement"[D13,group,class] = SUM ( HIBZM HI internal between zones movement i k\
[i!,D13,group,class] ) ~~|
"HIIM HI internal into-zone movement"[D14,group,class] = SUM ( HIBZM HI internal between zones movement i k\
[i!,D14,group,class] )
~
~ |
"HIOM HI internal out-of-zone movement"[D1,group,class] = SUM ( HIBZM HI internal between zones movement i k\
[D1,k!,group,class] ) ~~|
"HIOM HI internal out-of-zone movement"[D2,group,class] = SUM ( HIBZM HI internal between zones movement i k\
[D2,k!,group,class] ) ~~|
"HIOM HI internal out-of-zone movement"[D3,group,class] = SUM ( HIBZM HI internal between zones movement i k\
[D3,k!,group,class] ) ~~|
"HIOM HI internal out-of-zone movement"[D4,group,class] = SUM ( HIBZM HI internal between zones movement i k\
[D4,k!,group,class] ) ~~|
"HIOM HI internal out-of-zone movement"[D5,group,class] = SUM ( HIBZM HI internal between zones movement i k\
[D5,k!,group,class] ) ~~|
"HIOM HI internal out-of-zone movement"[D6,group,class] = SUM ( HIBZM HI internal between zones movement i k\
[D6,k!,group,class] ) ~~|
"HIOM HI internal out-of-zone movement"[D7,group,class] = SUM ( HIBZM HI internal between zones movement i k\
[D7,k!,group,class] ) ~~|
"HIOM HI internal out-of-zone movement"[D8,group,class] = SUM ( HIBZM HI internal between zones movement i k\
[D8,k!,group,class] ) ~~|
"HIOM HI internal out-of-zone movement"[D9,group,class] = SUM ( HIBZM HI internal between zones movement i k\
[D9,k!,group,class] ) ~~|
"HIOM HI internal out-of-zone movement"[D10,group,class] = SUM ( HIBZM HI internal between zones movement i k\
[D10,k!,group,class] ) ~~|
"HIOM HI internal out-of-zone movement"[D11,group,class] = SUM ( HIBZM HI internal between zones movement i k\
[D11,k!,group,class] ) ~~|
"HIOM HI internal out-of-zone movement"[D12,group,class] = SUM ( HIBZM HI internal between zones movement i k\
[D12,k!,group,class] ) ~~|
"HIOM HI internal out-of-zone movement"[D13,group,class] = SUM ( HIBZM HI internal between zones movement i k\
[D13,k!,group,class] ) ~~|
"HIOM HI internal out-of-zone movement"[D14,group,class] = SUM ( HIBZM HI internal between zones movement i k\
[D14,k!,group,class] )
~
~ |
HJ HI jobs i[i,class] = Business Establishments i[i,class] * BHC Business HI class[class\
]
~
~ |
HJ HI jobs k[D1,class] = HJ HI jobs i[D1,class] ~~|
HJ HI jobs k[D2,class] = HJ HI jobs i[D2,class] ~~|
HJ HI jobs k[D3,class] = HJ HI jobs i[D3,class] ~~|
HJ HI jobs k[D4,class] = HJ HI jobs i[D4,class] ~~|
HJ HI jobs k[D5,class] = HJ HI jobs i[D5,class] ~~|
HJ HI jobs k[D6,class] = HJ HI jobs i[D6,class] ~~|
HJ HI jobs k[D7,class] = HJ HI jobs i[D7,class] ~~|
HJ HI jobs k[D8,class] = HJ HI jobs i[D8,class] ~~|
HJ HI jobs k[D9,class] = HJ HI jobs i[D9,class] ~~|
HJ HI jobs k[D10,class] = HJ HI jobs i[D10,class] ~~|
HJ HI jobs k[D11,class] = HJ HI jobs i[D11,class] ~~|
HJ HI jobs k[D12,class] = HJ HI jobs i[D12,class] ~~|
HJ HI jobs k[D13,class] = HJ HI jobs i[D13,class] ~~|
HJ HI jobs k[D14,class] = HJ HI jobs i[D14,class]
~
~ |
HJC HI jobs class[class] = SUM ( HJ HI jobs i[i!,class] )
~
~ |
"HJR HI/job ratio"[i,class] = SUM ( HI High Income[i,group!,class] ) / HJ HI jobs i[i\
,class]
~
~ |
"HJRC HI/job ratio class"[class] = HC HI class[class] / HJC HI jobs class[class]
~ Dmnl
~ |
```

HLAM HI locational attractiveness multiplier i[i,class] = WITH LOOKUP(HCZA HI comparison zone i to average\
[i,class] , ([(0,0)-(2.25,2)],(0,0.7),(0.25,0.7),(0.5,0.8),(0.75,0.9),(1,1),(1.25,1.1\
),(1.5,1.2),(1.75,1.3),(2,1.4),(2.25,1.4)))
~
~ |
HLF HI layoff fraction[class] = WITH LOOKUP("HJRC HI/job ratio class"[class] , ([(0,\
0)-(2,0.7)],(0,0),(0.5,0.01),(1,0.05),(1.5,0.3),(2,0.6)))
~
~ |
"HMM HI/MI multiplier i"[i] = WITH LOOKUP("HMR HI/MI ratio"[i] , ([(0,0)-(0.2,2)],(0\
,0.2),(0.05,0.7),(0.1,1),(0.15,1.2),(0.2,1.3)))
~
~ |
"HMR HI/MI ratio"[i] = SUM (HI High Income[i,group!,class!]) / SUM (MI Middle Income\
[i,group!,class!])
~ Dmnl
~ |
HNZM HI net zone movement[i,group,class] = "HIIM HI internal into-zone movement"[i,group\
,class] - "HIOM HI internal out-of-zone movement"[i,group,class]
~
~ |
"HPR HI/population ratio i"[i] = SUM (HI High Income[i,group!,class!]) / SUM (MI Middle Income\
[i,group!,class!] + LI Low Income[i,group!,class!])
~ Dmnl
~ |
"HPR HI/population ratio" = SUM (HC HI class[class!]) / SUM (MC MI class[class!] +\
LC LI class[class!])
~
~ |
HSM HI supply multiplier[class] = WITH LOOKUP("HJRC HI/job ratio class"[class] , ([(\
0,0)-(2,3)],(0,2.3),(0.25,2.2),(0.5,2),(0.75,1.6),(1,1),(1.25,0.5),(1.5,0.2),(1.75,\
0.1),(2,0.05)))
~
~ |
HTM HI to MI[i,group,class] = HI High Income[i,group,class] * HLF HI layoff fraction[\
class]
~
~ |
JT Jobs total[class] = LJC LI jobs class[class] + MJC MI jobs class[class] + HJC HI jobs class\
[class]
~
~ |
LA LI arrivals[i,group,class] = LI Low Income[i,group,class] * WPAN Working Population Arrivals normal\
[group] * AMMP Attractiveness for migration multiplier perceived[i,class]
~ Person/year
~ |
LAMM LI arrivals mobility multiplier = WITH LOOKUP(LMA LI mobility average , ([(0,0)\
-(0.15,3)],(0,0.3),(0.025,0.7),(0.05,1),(0.075,1.2),(0.1,1.3),(0.125,1.4),(0.15,1.5\
)))
~ Dmnl
~ |
LC LI class[class] = SUM (LCD LI Class District[i!,class])
~
~ |
LCD LI Class District[i,class] = SUM (LI Low Income[i,group!,class])
~
~ |
LCZA LI comparison zone i to average[i,class] = AALJZ Accessibility attractiveness to LI jobs zone i\
[i,class] / AAALJAZ Average accessibility attractiveness to LI jobs all zones[class\
]
~
~ |
LD LI departures[i,group,class] = LI Low Income[i,group,class] * WPDN Working Population departures normal\
[group] * LDM LI departure multiplier[i,class]
~ Person/year
~ |
LDM LI departure multiplier[i,class] = WITH LOOKUP((1.44 * LN (AMM Attractiveness for migration multiplier\
[i,class])) , ([(-3,0)-(4,8)],(-3,8),(-2,4),(-1,2),(0,1),(1,0.25),(2,0.125),(3,0.1\

```
),(4,0.1) ) )
~
~ |
LI LI initial[i,autochtonen] = 6562.1, 9861, 4675.2, 12105.2, 10489.6, 12594.7, 12330.4\
, 16873.2, 1283, 23375.3, 15713.9, 9033.9, 2753.8, 3144.7 ~~|
LI LI initial[i,"w-allochtonen"] = 2008.1, 3399.2, 618.6, 2610, 1537.9, 2850.6, 2739.2\
, 2530.1, 105.6, 3245.5, 3008, 1047.1, 214.1, 378.8 ~~|
LI LI initial[i,"nw-allochtonen"] = 4799.3, 20648.3, 1574.1, 8978.6, 1949.2, 8279.5, \
19093.6, 8678.3, 120.2, 5817.3, 14644.1, 2997.6, 91.4, 264 ~~|
LI LI initial[i,"nw-allochtonen refugee"] = 29.3, 106.4, 9, 48.8, 14.8, 48, 98.4, 46.7\
, 0.7, 37.9, 73, 17.6, 0.8, 1.8 ~~|
LI LI initial[i,"w-allochtonen refugee"] = 0.9, 1.4, 0.7, 1.1, 0.8, 1.3, 1, 1.1, 0.05\
, 1.6, 1.1, 0.5, 0.14, 0.17
~
~ |
LI Low Income[i,group,class] = INTEG( LA LI arrivals[i,group,class] + MTL MI to LI[i,\
group,class] - LD LI departures[i,group,class] - LTM LI to MI[i,group,class] + LNZM LI net zone movement\
[i,group,class] + Education to LI Rate[i,group,class] - ( LI Low Income[i,group,class\
] * Exam Failure Exit Rate[i,group] / SUM ( Working Population[i,group,class!] ) ) \
+ ( Immigrant Arrival Rate[i,group] * Immigrant LI Constant[group] * Education LI Class Ratio\
[autochtonen,class] ) + ( Refugee Arrival Rate[i,group] * Refugee LI Constant[group\
] * Education LI Class Ratio[group,class] ) , LI LI initial[i,group] * ( 1 - Adult Education Initial\
[i] ) * ( LJ LI jobs i[i,class] / SUM ( LJ LI jobs i[i,class!] ) ) )
~
~ |
LI Low Income k[D1,group,class] = LI Low Income[D1,group,class] ~~|
LI Low Income k[D2,group,class] = LI Low Income[D2,group,class] ~~|
LI Low Income k[D3,group,class] = LI Low Income[D3,group,class] ~~|
LI Low Income k[D4,group,class] = LI Low Income[D4,group,class] ~~|
LI Low Income k[D5,group,class] = LI Low Income[D5,group,class] ~~|
LI Low Income k[D6,group,class] = LI Low Income[D6,group,class] ~~|
LI Low Income k[D7,group,class] = LI Low Income[D7,group,class] ~~|
LI Low Income k[D8,group,class] = LI Low Income[D8,group,class] ~~|
LI Low Income k[D9,group,class] = LI Low Income[D9,group,class] ~~|
LI Low Income k[D10,group,class] = LI Low Income[D10,group,class] ~~|
LI Low Income k[D11,group,class] = LI Low Income[D11,group,class] ~~|
LI Low Income k[D12,group,class] = LI Low Income[D12,group,class] ~~|
LI Low Income k[D13,group,class] = LI Low Income[D13,group,class] ~~|
LI Low Income k[D14,group,class] = LI Low Income[D14,group,class]
~
~ |
LIBZM LI internal between zones movement i k[i,k,group,class] = "WPIOMN Working Population internal out-of-zone movement normal"\
* ( ( ( LI Low Income[i,group,class] / ( AIMLM Attractiveness for internal migration LI multiplier i\
[i,class] * Cognitive Dissonance Multiplier[i,group] ) ) * ( LI Low Income k[k,group\
,class] * AIMLMP Attractiveness for internal migration LI multiplier perceived k[k,\
class] ) ) / LC LI class[class] )
~
~ |
"LIIM LI internal into-zone movement"[D1,group,class] = SUM ( LIBZM LI internal between zones movement i k\
[i!,D1,group,class] ) ~~|
"LIIM LI internal into-zone movement"[D2,group,class] = SUM ( LIBZM LI internal between zones movement i k\
[i!,D2,group,class] ) ~~|
"LIIM LI internal into-zone movement"[D3,group,class] = SUM ( LIBZM LI internal between zones movement i k\
[i!,D3,group,class] ) ~~|
"LIIM LI internal into-zone movement"[D4,group,class] = SUM ( LIBZM LI internal between zones movement i k\
[i!,D4,group,class] ) ~~|
"LIIM LI internal into-zone movement"[D5,group,class] = SUM ( LIBZM LI internal between zones movement i k\
[i!,D5,group,class] ) ~~|
"LIIM LI internal into-zone movement"[D6,group,class] = SUM ( LIBZM LI internal between zones movement i k\
[i!,D6,group,class] ) ~~|
"LIIM LI internal into-zone movement"[D7,group,class] = SUM ( LIBZM LI internal between zones movement i k\
[i!,D7,group,class] ) ~~|
"LIIM LI internal into-zone movement"[D8,group,class] = SUM ( LIBZM LI internal between zones movement i k\
[i!,D8,group,class] ) ~~|
"LIIM LI internal into-zone movement"[D9,group,class] = SUM ( LIBZM LI internal between zones movement i k\
[i!,D9,group,class] ) ~~|
"LIIM LI internal into-zone movement"[D10,group,class] = SUM ( LIBZM LI internal between zones movement i k\
```

```
[i!,D10,group,class] ) ~~|
"LIIM LI internal into-zone movement"[D11,group,class] = SUM ( LIBZM LI internal between zones movement i k\
[i!,D11,group,class] ) ~~|
"LIIM LI internal into-zone movement"[D12,group,class] = SUM ( LIBZM LI internal between zones movement i k\
[i!,D12,group,class] ) ~~|
"LIIM LI internal into-zone movement"[D13,group,class] = SUM ( LIBZM LI internal between zones movement i k\
[i!,D13,group,class] ) ~~|
"LIIM LI internal into-zone movement"[D14,group,class] = SUM ( LIBZM LI internal between zones movement i k\
[i!,D14,group,class] )
~
~ |
"LIOM LI internal out-of-zone movement"[D1,group,class] = SUM ( LIBZM LI internal between zones movement i k\
[D1,k!,group,class] ) ~~|
"LIOM LI internal out-of-zone movement"[D2,group,class] = SUM ( LIBZM LI internal between zones movement i k\
[D2,k!,group,class] ) ~~|
"LIOM LI internal out-of-zone movement"[D3,group,class] = SUM ( LIBZM LI internal between zones movement i k\
[D3,k!,group,class] ) ~~|
"LIOM LI internal out-of-zone movement"[D4,group,class] = SUM ( LIBZM LI internal between zones movement i k\
[D4,k!,group,class] ) ~~|
"LIOM LI internal out-of-zone movement"[D5,group,class] = SUM ( LIBZM LI internal between zones movement i k\
[D5,k!,group,class] ) ~~|
"LIOM LI internal out-of-zone movement"[D6,group,class] = SUM ( LIBZM LI internal between zones movement i k\
[D6,k!,group,class] ) ~~|
"LIOM LI internal out-of-zone movement"[D7,group,class] = SUM ( LIBZM LI internal between zones movement i k\
[D7,k!,group,class] ) ~~|
"LIOM LI internal out-of-zone movement"[D8,group,class] = SUM ( LIBZM LI internal between zones movement i k\
[D8,k!,group,class] ) ~~|
"LIOM LI internal out-of-zone movement"[D9,group,class] = SUM ( LIBZM LI internal between zones movement i k\
[D9,k!,group,class] ) ~~|
"LIOM LI internal out-of-zone movement"[D10,group,class] = SUM ( LIBZM LI internal between zones movement i k\
[D10,k!,group,class] ) ~~|
"LIOM LI internal out-of-zone movement"[D11,group,class] = SUM ( LIBZM LI internal between zones movement i k\
[D11,k!,group,class] ) ~~|
"LIOM LI internal out-of-zone movement"[D12,group,class] = SUM ( LIBZM LI internal between zones movement i k\
[D12,k!,group,class] ) ~~|
"LIOM LI internal out-of-zone movement"[D13,group,class] = SUM ( LIBZM LI internal between zones movement i k\
[D13,k!,group,class] ) ~~|
"LIOM LI internal out-of-zone movement"[D14,group,class] = SUM ( LIBZM LI internal between zones movement i k\
[D14,k!,group,class] )
~
~ |
LJ LI jobs i[i,class] = Business Establishments i[i,class] * BLC Business LI class[class\
] + LJP LI job program i[i,class]
~
~ |
LJ LI jobs k[D1,class] = LJ LI jobs i[D1,class] ~~|
LJ LI jobs k[D2,class] = LJ LI jobs i[D2,class] ~~|
LJ LI jobs k[D3,class] = LJ LI jobs i[D3,class] ~~|
LJ LI jobs k[D4,class] = LJ LI jobs i[D4,class] ~~|
LJ LI jobs k[D5,class] = LJ LI jobs i[D5,class] ~~|
LJ LI jobs k[D6,class] = LJ LI jobs i[D6,class] ~~|
LJ LI jobs k[D7,class] = LJ LI jobs i[D7,class] ~~|
LJ LI jobs k[D8,class] = LJ LI jobs i[D8,class] ~~|
LJ LI jobs k[D9,class] = LJ LI jobs i[D9,class] ~~|
LJ LI jobs k[D10,class] = LJ LI jobs i[D10,class] ~~|
LJ LI jobs k[D11,class] = LJ LI jobs i[D11,class] ~~|
LJ LI jobs k[D12,class] = LJ LI jobs i[D12,class] ~~|
LJ LI jobs k[D13,class] = LJ LI jobs i[D13,class] ~~|
LJ LI jobs k[D14,class] = LJ LI jobs i[D14,class]
~
~ |
LJC LI jobs class[class] = SUM ( LJ LI jobs i[i!,class] )
~
~ |
"LJM LI/job multiplier"[i,class] = WITH LOOKUP( "LJR LI/jobs ratio"[i,class] , ([(0,0\
)-(3,2.75)],(0,2),(0.25,2),(0.5,1.9),(0.75,1.6),(1,1),(1.25,0.6),(1.5,0.4),(1.75,0.3\
),(2,0.2),(2.25,0.15),(2.5,0.1),(2.75,0.05),(3,0.02) ) )
~
```

```
~ |
"LJR LI/jobs ratio"[i,class] = SUM ( LI Low Income[i,group!,class] ) / LJ LI jobs i[i\
,class]
~
~ |
LLAM LI locational attractiveness multiplier i[i,class] = WITH LOOKUP( LCZA LI comparison zone i to average\
[i,class] , ([(0,0)-(2,2)],(0,0.4),(0.25,0.4),(0.5,0.5),(0.75,0.65),(1,1),(1.25,1.3\
),(1.5,1.5),(1.75,1.6),(2,1.7) ) )
~
~ |
LM LI mobility[i,class] = SUM ( LTMP LI to MI perceived[i,group!,class] ) / SUM ( LI Low Income\
[i,group!,class] )
~ Fraction/year
~ |
LMA LI mobility average = SUM ( LM LI mobility[i!,class!] ) / 14
~
~ |
LMM LI mobility multiplier[i,class] = MSM MI supply multiplier[i,class] * "MLM MI/LI multiplier i"\
[i] * LEM LI educational multiplier
~ Dmnl
~ |
LMMP LI mobility multiplier perceived[i,class] = INTEG( CLMMP Change in LMMP[i,class]\
, 1)
~ Dmnl
~ |
LMMPT LI mobility multiplier perception time = 10
~ year
~ |
LMN LI mobility normal = 0.05
~ Fraction/year
~ |
LNZM LI net zone movement[i,group,class] = "LIIM LI internal into-zone movement"[i,group\
,class] - "LIOM LI internal out-of-zone movement"[i,group,class]
~
~ |
LTM LI to MI[i,group,class] = LMN LI mobility normal * LI Low Income[i,group,class] *\
LMMP LI mobility multiplier perceived[i,class] * Language Labor Multiplier[i,group\
] * Ethnic Network Multiplier[i,group] + LTP LI training program[i,group,class]
~ Person/year
~ |
LTMN LI to MI net = SUM ( LTM LI to MI[i!,group!,class!] ) - SUM ( MTL MI to LI[i!,group\
!,class!] )
~~
~ :SUPPLEMENTARY
|
LTMP LI to MI perceived[i,group,class] = INTEG( CLTMP Change in LTMP[i,group,class] ,\
LI Low Income[i,group,class] )
~ Dmnl
~ |
LTMPT LI to MI perception time = 10
~ year
~ |
MA MI arrivals[i,group,class] = MI Middle Income[i,group,class] * WPAN Working Population Arrivals normal\
[group] * MAMP MI arrival multiplier perceived[i,class]
~ Person/year
~ |
MAHM MI arrival housing multiplier[i] = WITH LOOKUP( "MHR MI/housing ratio"[i] , ([(0\
,0)-(3,2)],(0,1.3),(0.5,1.2),(1,1),(1.5,0.5),(2,0.2),(2.5,0.1),(3,0.05) ) )
~
~ |
MAHM MI arrival housing multiplier i[i] = WITH LOOKUP( "HMR Housing/MI ratio i"[i] , \
([(0,0)-(3,4)],(0,0.05),(0.5,0.3),(1,1),(1.5,1.25),(2,1.5),(2.5,1.8),(3,2) ) )
~
~ |
MAJM MI arrival job multiplier[i,class] = WITH LOOKUP( "MJR MI/job ratio"[i,class] , \
([(0,0)-(2,3)],(0,2.6),(0.25,2.6),(0.5,2.4),(0.75,1.8),(1,1),(1.25,0.4),(1.5,0.2),(\
1.75,0.1),(2,0.05) ) )
~ Dmnl
```

```
~ |
MALM MI arrival LI multiplier = WITH LOOKUP( "MLRT MI/LI ratio total" , ([(0,0)-(5,2)\
],(0,0.4),(1,0.8),(2,1),(3,1.2),(4,1.3),(5,1.3) ) )
~ Dmnl
~ |
MALM MI arrival LI multiplier i[i] = WITH LOOKUP( "MLR MI/LI ratio"[i] , ([(0,0)-(5,2\
)],(0,0.4),(1,0.8),(2,1),(3,1.2),(4,1.3),(5,1.3) ) )
~ Dmnl
~ |
MAM MI arrival multiplier[i,class] = MAJM MI arrival job multiplier[i,class] * MALM MI arrival LI multiplier\
* MATM MI arrival tax multiplier * MAHM MI arrival housing multiplier[i]
~
~ |
MAMP MI arrival multiplier perceived[i,class] = INTEG( CMAMP Change in MAMP[i,class] \
, 1)
~
~ |
MAMPT MI arrival multiplier perception time = 15
~ year
~ |
MC MI class[class] = SUM ( MCD MI Class District[i!,class] )
~
~ |
MCD MI Class District[i,class] = SUM ( MI Middle Income[i,group!,class] )
~
~ |
MCZA MI comparison zone i to average[i,class] = AAMJZ Accessibility attractiveness to MI jobs zone i\
[i,class] / AAAMJAZ Average accessibility attractiveness to MI jobs all zones[class\
]
~
~ |
MD MI departures[i,group,class] = MI Middle Income[i,group,class] * WPDN Working Population departures normal\
[group] * MDM MI departure multiplier[i,class]
~ Person/year
~ |
MDM MI departure multiplier[i,class] = WITH LOOKUP( ( 1.44 * LN ( MAM MI arrival multiplier\
[i,class] ) ) , ([(-3,0)-(4,8)],(-3,8),(-2,4),(-1,2),(0,1),(1,0.5),(2,0.25),(3,0.125\
),(4,0.1) ) )
~ Dmnl
~ |
MI MI initial[i,autochtonen] = 4331, 5011.4, 3146.7, 6795.9, 7492.5, 6869.8, 6266.3, \
10737.5, 1480.4, 19656.5, 7365.9, 8052, 2893, 3930.9 ~~|
MI MI initial[i,"w-allochtonen"] = 1325.4, 1727.5, 416.3, 1465.3, 1098.5, 1554.9, 1392\
, 1610.1, 121.9, 2729.1, 1410, 933.2, 225.1, 473.4 ~~|
MI MI initial[i,"nw-allochtonen"] = 3167.5, 10493.4, 1059.5, 5040.6, 1392.3, 4516.1, \
9703.3, 5522.5, 138.7, 4891.8, 6864.4, 2671.8, 96.1, 330 ~~|
MI MI initial[i,"nw-allochtonen refugee"] = 14.4, 47.8, 4.8, 23, 6.3, 20.6, 44.2, 25.2\
, 0.6, 22.3, 31.3, 12.2, 0.4, 1.5 ~~|
MI MI initial[i,"w-allochtonen refugee"] = 0.4, 0.6, 0.1, 0.5, 0.4, 0.5, 0.5, 0.5, 0.04\
, 0.9, 0.5, 0.3, 0.08, 0.2
~
~ |
MI Middle Income[i,group,class] = INTEG( LTM LI to MI[i,group,class] + MA MI arrivals\
[i,group,class] - MD MI departures[i,group,class] - MTH MI to HI[i,group,class] - MTL MI to LI\
[i,group,class] + MNZM MI net zone movement[i,group,class] + Education to MI Rate[i\
,group,class] + HTM HI to MI[i,group,class] - ( MI Middle Income[i,group,class] * Exam Failure Exit Rate\
[i,group] / SUM ( Working Population[i,group,class!] ) ) + ( Immigrant Arrival Rate\
[i,group] * Immigrant MI Constant[group] * Education MI Class Ratio[class] ) + ( Refugee Arrival Rate\
[i,group] * Refugee MI Constant[group] * Education MI Class Ratio[class] ) , MI MI initial\
[i,group] * ( 1 - Adult Education Initial[i] ) * ( MJ MI jobs i[i,class] / SUM ( MJ MI jobs i\
[i,class!] ) ) )
~
~ |
MI Middle Income k[D1,group,class] = MI Middle Income[D1,group,class] ~~|
MI Middle Income k[D2,group,class] = MI Middle Income[D2,group,class] ~~|
MI Middle Income k[D3,group,class] = MI Middle Income[D3,group,class] ~~|
MI Middle Income k[D4,group,class] = MI Middle Income[D4,group,class] ~~|
MI Middle Income k[D5,group,class] = MI Middle Income[D5,group,class] ~~|
```

MI Middle Income k[D6,group,class] = MI Middle Income[D6,group,class] ~~|
MI Middle Income k[D7,group,class] = MI Middle Income[D7,group,class] ~~|
MI Middle Income k[D8,group,class] = MI Middle Income[D8,group,class] ~~|
MI Middle Income k[D9,group,class] = MI Middle Income[D9,group,class] ~~|
MI Middle Income k[D10,group,class] = MI Middle Income[D10,group,class] ~~|
MI Middle Income k[D11,group,class] = MI Middle Income[D11,group,class] ~~|
MI Middle Income k[D12,group,class] = MI Middle Income[D12,group,class] ~~|
MI Middle Income k[D13,group,class] = MI Middle Income[D13,group,class] ~~|
MI Middle Income k[D14,group,class] = MI Middle Income[D14,group,class]
~
~ |
MIBZM MI internal between zones movement i k[i,k,group,class] = "WPIOMN Working Population internal out-of-zone movement normal"\
* (((MI Middle Income[i,group,class] / (AIMMM Attractiveness for internal migration MI multiplier i\
[i,class] * Cognitive Dissonance Multiplier[i,group])) * (MI Middle Income k[k,group\
,class] * AIMMMP Attractiveness for internal migration MI multiplier perceived k[k,\
class])) / MC MI class[class])
~
~ |
"MIIM MI internal into-zone movement"[D1,group,class] = SUM (MIBZM MI internal between zones movement i k\
[i!,D1,group,class]) ~~|
"MIIM MI internal into-zone movement"[D2,group,class] = SUM (MIBZM MI internal between zones movement i k\
[i!,D2,group,class]) ~~|
"MIIM MI internal into-zone movement"[D3,group,class] = SUM (MIBZM MI internal between zones movement i k\
[i!,D3,group,class]) ~~|
"MIIM MI internal into-zone movement"[D4,group,class] = SUM (MIBZM MI internal between zones movement i k\
[i!,D4,group,class]) ~~|
"MIIM MI internal into-zone movement"[D5,group,class] = SUM (MIBZM MI internal between zones movement i k\
[i!,D5,group,class]) ~~|
"MIIM MI internal into-zone movement"[D6,group,class] = SUM (MIBZM MI internal between zones movement i k\
[i!,D6,group,class]) ~~|
"MIIM MI internal into-zone movement"[D7,group,class] = SUM (MIBZM MI internal between zones movement i k\
[i!,D7,group,class]) ~~|
"MIIM MI internal into-zone movement"[D8,group,class] = SUM (MIBZM MI internal between zones movement i k\
[i!,D8,group,class]) ~~|
"MIIM MI internal into-zone movement"[D9,group,class] = SUM (MIBZM MI internal between zones movement i k\
[i!,D9,group,class]) ~~|
"MIIM MI internal into-zone movement"[D10,group,class] = SUM (MIBZM MI internal between zones movement i k\
[i!,D10,group,class]) ~~|
"MIIM MI internal into-zone movement"[D11,group,class] = SUM (MIBZM MI internal between zones movement i k\
[i!,D11,group,class]) ~~|
"MIIM MI internal into-zone movement"[D12,group,class] = SUM (MIBZM MI internal between zones movement i k\
[i!,D12,group,class]) ~~|
"MIIM MI internal into-zone movement"[D13,group,class] = SUM (MIBZM MI internal between zones movement i k\
[i!,D13,group,class]) ~~|
"MIIM MI internal into-zone movement"[D14,group,class] = SUM (MIBZM MI internal between zones movement i k\
[i!,D14,group,class])
~
~ |
"MIOM MI internal out-of-zone movement"[D1,group,class] = SUM (MIBZM MI internal between zones movement i k\
[D1,k!,group,class]) ~~|
"MIOM MI internal out-of-zone movement"[D2,group,class] = SUM (MIBZM MI internal between zones movement i k\
[D2,k!,group,class]) ~~|
"MIOM MI internal out-of-zone movement"[D3,group,class] = SUM (MIBZM MI internal between zones movement i k\
[D3,k!,group,class]) ~~|
"MIOM MI internal out-of-zone movement"[D4,group,class] = SUM (MIBZM MI internal between zones movement i k\
[D4,k!,group,class]) ~~|
"MIOM MI internal out-of-zone movement"[D5,group,class] = SUM (MIBZM MI internal between zones movement i k\
[D5,k!,group,class]) ~~|
"MIOM MI internal out-of-zone movement"[D6,group,class] = SUM (MIBZM MI internal between zones movement i k\
[D6,k!,group,class]) ~~|
"MIOM MI internal out-of-zone movement"[D7,group,class] = SUM (MIBZM MI internal between zones movement i k\
[D7,k!,group,class]) ~~|
"MIOM MI internal out-of-zone movement"[D8,group,class] = SUM (MIBZM MI internal between zones movement i k\
[D8,k!,group,class]) ~~|
"MIOM MI internal out-of-zone movement"[D9,group,class] = SUM (MIBZM MI internal between zones movement i k\
[D9,k!,group,class]) ~~|
"MIOM MI internal out-of-zone movement"[D10,group,class] = SUM (MIBZM MI internal between zones movement i k\

```
[D10,k!,group,class] ) ~~|
"MIOM MI internal out-of-zone movement"[D11,group,class] = SUM ( MIBZM MI internal between zones movement i k\
[D11,k!,group,class] ) ~~|
"MIOM MI internal out-of-zone movement"[D12,group,class] = SUM ( MIBZM MI internal between zones movement i k\
[D12,k!,group,class] ) ~~|
"MIOM MI internal out-of-zone movement"[D13,group,class] = SUM ( MIBZM MI internal between zones movement i k\
[D13,k!,group,class] ) ~~|
"MIOM MI internal out-of-zone movement"[D14,group,class] = SUM ( MIBZM MI internal between zones movement i k\
[D14,k!,group,class] )
~
~ |
MJ MI jobs i[i,class] = Business Establishments i[i,class] * BMC Business MI class[class\
]
~
~ |
MJ MI jobs k[D1,class] = MJ MI jobs i[D1,class] ~~|
MJ MI jobs k[D2,class] = MJ MI jobs i[D2,class] ~~|
MJ MI jobs k[D3,class] = MJ MI jobs i[D3,class] ~~|
MJ MI jobs k[D4,class] = MJ MI jobs i[D4,class] ~~|
MJ MI jobs k[D5,class] = MJ MI jobs i[D5,class] ~~|
MJ MI jobs k[D6,class] = MJ MI jobs i[D6,class] ~~|
MJ MI jobs k[D7,class] = MJ MI jobs i[D7,class] ~~|
MJ MI jobs k[D8,class] = MJ MI jobs i[D8,class] ~~|
MJ MI jobs k[D9,class] = MJ MI jobs i[D9,class] ~~|
MJ MI jobs k[D10,class] = MJ MI jobs i[D10,class] ~~|
MJ MI jobs k[D11,class] = MJ MI jobs i[D11,class] ~~|
MJ MI jobs k[D12,class] = MJ MI jobs i[D12,class] ~~|
MJ MI jobs k[D13,class] = MJ MI jobs i[D13,class] ~~|
MJ MI jobs k[D14,class] = MJ MI jobs i[D14,class]
~
~ |
MJC MI jobs class[class] = SUM ( MJ MI jobs i[i!,class] )
~
~ |
"MJR MI/job ratio"[i,class] = SUM ( MI Middle Income[i,group!,class] ) / MJ MI jobs i\
[i,class]
~
~ |
MLAM MI locational attractiveness multiplier i[i,class] = WITH LOOKUP( MCZA MI comparison zone i to average\
[i,class] , ([(0,0)-(2,2)],(0,0.5),(0.25,0.5),(0.5,0.6),(0.75,0.75),(1,1),(1.25,1.25\
),(1.5,1.4),(1.75,1.5),(2,1.6) ) )
~
~ |
MLF MI layoff fraction[i,class] = WITH LOOKUP( "MJR MI/job ratio"[i,class] , ([(0,0)-\
(2,0.7)],(0,0),(0.5,0.01),(1,0.05),(1.5,0.3),(2,0.6) ) )
~
~ |
"MLM MI/LI multiplier i"[i] = WITH LOOKUP( "MLR MI/LI ratio"[i] , ([(0,0)-(5,2)],(0,0.2\
),(1,0.7),(2,1),(3,1.2),(4,1.3),(5,1.4) ) )
~ Dmnl
~ |
"MLR MI/LI ratio"[i] = SUM ( MI Middle Income[i,group!,class!] ) / SUM ( LI Low Income\
[i,group!,class!] )
~
~ |
"MLRT MI/LI ratio total" = SUM ( MC MI class[class!] ) / SUM ( LC LI class[class!] )
~
~ |
MM MI mobility i[i] = SUM ( MTH MI to HI[i,group!,class!] ) / SUM ( MI Middle Income[\
i,group!,class!] )
~~
~ :SUPPLEMENTARY
|
MMM MI mobility multiplier i[i,class] = HSM HI supply multiplier[class] * "HMM HI/MI multiplier i"\
[i] * MEM MI educational multiplier
~ Dmnl
~ |
MMMP MI mobility multiplier perceived i[i,class] = INTEG( CMMMP Change in MMMP i[i,class\
```

```
] , 1)
~
~ |
MMMPT MI mobility multiplier perception time = 15
~ year
~ |
MMN MI mobility normal = 0.005
~ Fraction/year
~ |
MNZM MI net zone movement[i,group,class] = "MIIM MI internal into-zone movement"[i,group\
,class] - "MIOM MI internal out-of-zone movement"[i,group,class]
~
~ |
"MRPT MI/job ratio perception time" = 5
~ year
~ |
"MRTP MI/job ratio total perceived" = INTEG( CMRTP Change in MRTP , 1)
~
~ |
MSM MI supply multiplier[i,class] = WITH LOOKUP( "MJR MI/job ratio"[i,class] , ([(0,0\
)-(2,3)],(0,2.4),(0.5,2),(1,1),(1.5,0.4),(2,0.2) ) )
~ Dmnl
~ |
MTH MI to HI[i,group,class] = MI Middle Income[i,group,class] * MMN MI mobility normal\
* MMMP MI mobility multiplier perceived i[i,class] * Language Labor Multiplier[i,group\
] + MTP MI training program[i,group,class]
~ Person/year
~ |
MTL MI to LI[i,group,class] = MI Middle Income[i,group,class] * MLF MI layoff fraction\
[i,class]
~ Person/year
~ |
Total Arrivals[i,group] = SUM ( HA HI arrivals[i,group,class!] + MA MI arrivals[i,group\
,class!] + LA LI arrivals[i,group,class!] )
~
~ |
"Worker/Job ratio class"[class] = SUM ( Working Population[i!,group!,class] ) / JT Jobs total\
[class]
~
~ |
WPAN Working Population Arrivals normal[autochtonen] = 0.037 ~~|
WPAN Working Population Arrivals normal["nw-allochtonen"] = 0.037 ~~|
WPAN Working Population Arrivals normal["w-allochtonen"] = 0.037 ~~|
WPAN Working Population Arrivals normal[refugee] = 0
~ Fraction/year
~ |
WPDN Working Population departures normal[non refugee] = 0.047 ~~|
WPDN Working Population departures normal[refugee] = 0
~ Fraction/year
~ |
"WPIOMN Working Population internal out-of-zone movement normal" = 0.028
~
~ |
********************************************************
.Land Use
********************************************************~
|
AAHJAZ Average accessibility to HI jobs all zones = SUM ( ( HJ HI jobs k[k!,class!] )\
/ TDFC Trip distribution function construction i[i!,k!] ) / 14
~
~ |
AAMJAZ Average accessibility to MI jobs all zones = SUM ( ( MJ MI jobs k[k!,class!] )\
/ TDFC Trip distribution function construction i[i!,k!] ) / 14
~
~ |
AHJZ Accessibility to HI jobs zone i[i] = SUM ( HJ HI jobs k[k!,class!] / TDFC Trip distribution function construction i\
[i,k!] )
~
```

~ |
AMJZ Accessibility to MI jobs zone i[i] = SUM (MJ MI jobs k[k!,class!] / TDFC Trip distribution function construction i\
[i,k!])
~
~ |
AREA Land i[i] = 438, 503, 1514, 515, 1171, 1046, 635, 1182, 156, 1798, 1139, 981, 1399\
, 452
~
~ |
AREA Land total = SUM (AREA Land i[i!])
~
~ |
Business Establishments i[i,class] = INTEG(NBC New Business construction i[i,class] \
, Business Establishments initial[i,class])
~ productive unit
~ |
Business Establishments initial[i,A] = 2.7, 27, 14, 10.9, 8, 4.2, 30.1, 14.3, 0.5, 11.6\
, 39.6, 7.1, 65.1, 7.8 ~~|
Business Establishments initial[i,"B-F"] = 83.2, 284.1, 138.5, 213.5, 210.7, 206.2, 396.4\
, 570.9, 58.8, 630.3, 413.9, 331.9, 82.52, 122.6 ~~|
Business Establishments initial[i,"G+I"] = 507.1, 671.1, 226.8, 635.7, 552.7, 612.1, \
957.7, 859.7, 61.6, 1315.5, 711.9, 589.4, 185, 214.9 ~~|
Business Establishments initial[i,"H+J"] = 160.8, 320.7, 94, 241.3, 191.5, 247.8, 288.1\
, 369.6, 24.9, 555.4, 266.1, 209.9, 33.6, 67.5 ~~|
Business Establishments initial[i,"K-L"] = 206.9, 153.8, 95.8, 153, 385, 331.2, 165.4\
, 210.3, 23.1, 604.9, 117.9, 126.1, 84.9, 62.9 ~~|
Business Establishments initial[i,"M-N"] = 520.1, 733.4, 155.6, 630.4, 640.8, 727, 613.4\
, 442.7, 40.2, 1225.7, 358.5, 284.7, 77.6, 115.2 ~~|
Business Establishments initial[i,"R-U"] = 163.9, 480.5, 77, 438.4, 247.9, 383.2, 342.4\
, 286.1, 25.5, 486.9, 280.3, 177.6, 43.3, 92.2
~
~ |
Business Opening Normal[A] = 0.0046 ~~|
Business Opening Normal["B-F"] = 0.0386 ~~|
Business Opening Normal["G+I"] = 0.0202 ~~|
Business Opening Normal["H+J"] = 0.0539 ~~|
Business Opening Normal["K-L"] = 0.0231 ~~|
Business Opening Normal["M-N"] = 0.0662 ~~|
Business Opening Normal["R-U"] = 0.0591
~ productive unit/year
~ |
CHHA Change in HHA[i] = (SUM (HH HI housing i[i,type!]) - HHA HI housing average i\
[i]) / HHAT HI housing averaging time
~ Dmnl/year
~ |
CMHA Change in MHA[i] = (SUM (MH MI housing i[i,type!]) - MHA MI housing average i\
[i]) / MHAT MI housing averaging time
~
~ |
CNEA Change in NEA = (SUM (NBC New Business construction i[i!,class!]) - NEA New enterprise average\
) / NEAT New enterprise averaging time
~ productive unit/year
~ |
D Distance i k[i,k] = 1.05, 2, 3.68, 1.81, 3.9, 3.35, 3.18, 5.93, 6.68, 6.66, 3.28, 10.15\
, 24.31, 15.64; 2, 1.12, 3.73, 2.83, 5.64, 5.08, 3.76, 6.75, 4.72, 8.65, 2.28, 8.15\
, 23.21, 14; 3.68, 3.73, 1.95, 2.08, 4.24, 6.63, 6.8, 9.61, 6.23, 8.01, 5.99, 9.9, \
20.9, 13.19; 1.81, 2.83, 2.08, 1.13, 3, 4.54, 4.97, 7.65, 6.83, 6.5, 4.8, 10.49, 22.98\
, 14.91; 3.9, 5.64, 4.24, 3, 1.71, 4.34, 6.32, 8.2, 9.83, 3.78, 7.17, 13.49, 24.53,\
17.42; 3.35, 5.08, 6.63, 4.54, 4.34, 1.62, 2.91, 3.89, 9.76, 4.82, 5.08, 12.98, 27.5\
, 18.97; 3.18, 3.76, 6.8, 4.97, 6.32, 2.91, 1.26, 2.98, 7.84, 7.69, 2.58, 10.65, 26.98\
, 17.57; 5.93, 6.75, 9.61, 7.65, 8.2, 3.89, 2.98, 1.72, 10.6, 8.25, 5.27, 13.02, 29.96\
, 20.43; 6.68, 4.72, 6.23, 6.83, 9.83, 9.76, 7.84, 10.6, 0.62, 13.19, 5.31, 3.71, 20.72\
, 9.92; 6.66, 8.65, 8.01, 6.5, 3.78, 4.82, 7.69, 8.25, 13.19, 2.12, 9.5, 16.77, 28.08\
, 21.2; 3.28, 2.28, 5.99, 4.8, 7.17, 5.08, 2.58, 5.27, 5.31, 9.5, 1.69, 8.07, 24.98\
, 15.17; 10.15, 8.15, 9.9, 10.49, 13.49, 12.98, 10.65, 13.02, 3.71, 16.77, 8.07, 1.57\
, 20.28, 8.98; 24.31, 23.21, 20.9, 22.98, 24.53, 27.5, 26.98, 29.96, 20.72, 28.08, \
24.98, 20.28, 1.87, 11.49; 15.64, 14, 13.19, 14.91, 17.42, 18.97, 17.57, 20.43, 9.92\
, 21.2, 15.17, 8.98, 11.49, 1.06;

```
~
~ |
"EHJM Enterprise HI/job multiplier" = WITH LOOKUP( SUM ( "HJRC HI/job ratio class"[class\
!] ) / 7, ([(0,0)-(2,2)],(0,0.1),(0.25,0.15),(0.5,0.3),(0.75,0.5),(1,1),(1.25,1.4),\
(1.5,1.7),(1.75,1.9),(2,2) ) )
~
~ |
ELM Enterprise land multiplier[i] = WITH LOOKUP( LFO Land fraction occupied area i[i]\
, ([(0,0)-(1,2)],(0,1),(0.1,1.15),(0.2,1.3),(0.3,1.4),(0.4,1.45),(0.5,1.4),(0.6,1.3\
),(0.7,1),(0.8,0.7),(0.9,0.4),(1,0) ) )
~
~ |
EM Enterprise multiplier[i] = "EHJM Enterprise HI/job multiplier" * "EMJM Enterprise MI/job multiplier"\
* ELM Enterprise land multiplier[i] * ETM Enterprise tax multiplier
~
~ |
"EMJM Enterprise MI/job multiplier" = WITH LOOKUP( "MRTP MI/job ratio total perceived"\
, ([(0,0)-(2,2)],(0,0),(0.25,0.05),(0.5,0.15),(0.75,0.4),(1,1),(1.25,1.5),(1.5,1.7\
),(1.75,1.8),(2,1.8) ) )
~
~ |
HAHM HI arrival housing multiplier[i] = WITH LOOKUP( "HHR HI/housing ratio"[i] , ([(0\
,0)-(3,1.5)],(0,1.3),(0.5,1.2),(1,1),(1.5,0.5),(2,0.2),(2.5,0.1),(3,0.05) ) )
~ Dmnl
~ |
HAHM HI arrival housing multiplier i[i] = WITH LOOKUP( "HHR Housing/HI ratio i"[i] , \
([(0,0)-(3,4)],(0,0.05),(0.5,0.4),(1,1),(1.5,1.5),(2,2),(2.5,2.2),(3,2.5) ) )
~
~ |
HBSR Housing units to business structures ratio = SUM ( HUT Housing units total urban area\
[type!] ) / PUT Productive units total urban area
~~
~ :SUPPLEMENTARY
|
HH HI housing i[i,type] = INTEG( HHC HI housing construction i[i,type] - HHO HI housing obsolescence i\
[i,type] , HHI HI housing initial i[i,type] )
~
~ |
HHA HI housing average i[i] = INTEG( CHHA Change in HHA[i] , SUM ( HH HI housing i[i,\
type!] ) * ( 1 - HHGRI HI housing growth rate initial * HHAT HI housing averaging time\
) )
~
~ |
HHAM HI housing adequacy multiplier[i] = WITH LOOKUP( "HHR HI/housing ratio"[i] , ([(\
0,0)-(2,6)],(0,0),(0.25,0.001),(0.5,0.01),(0.75,0.2),(1,1),(1.25,3),(1.5,4.6),(1.75\
,5.6),(2,6) ) )
~ Dmnl
~ |
HHAT HI housing averaging time = 10
~ year
~ |
HHC HI housing construction i[i,type] = HHCD HI housing construction desired i[i,type\
] * Construction ratio total
~ housing units/year
~ |
HHCD HI housing construction desired i[i,type] = HH HI housing i[i,type] * Housing Construction Normal\
[type] * HHM HI housing multiplier i[i] + HHCP HI housing construction program i[i,\
type]
~
~ |
HHGM HI housing growth factor i[i] = WITH LOOKUP( HHGR HI housing growth rate[i] , ([\
(-0.1,0)-(0.2,3)],(-0.1,0.8),(-0.05,0.9),(0,1),(0.05,1.1),(0.1,1.2),(0.15,1.3),(0.2\
,1.4) ) )
~
~ |
HHGR HI housing growth rate[i] = ( SUM ( HH HI housing i[i,type!] ) - HHA HI housing average i\
[i] ) / ( SUM ( HH HI housing i[i,type!] ) * HHAT HI housing averaging time )
~
```

```
~ |
HHGRI HI housing growth rate initial = 0.0045
~
~ |
HHI HI housing initial i[i,single] = 28.1, 119.7, 370.1, 86.9, 2506.5, 283.6, 693.2, \
1153.3, 337.9, 3650.9, 356.7, 1407.1, 842.2, 840.7 ~~|
HHI HI housing initial i[i,multi] = 2782.6, 2872.5, 718.3, 2810.3, 3606.9, 3768, 2320.7\
, 2050.4, 59.6, 5041.7, 1741.3, 1018.9, 311.5, 414.1
~
~ |
HHLA HI housing location attractiveness i[i] = WITH LOOKUP( AHJZ Accessibility to HI jobs zone i\
[i] / AAHJAZ Average accessibility to HI jobs all zones , ([(0,0)-(2.25,6)],(0,0.6)\
,(0.25,0.6),(0.5,0.7),(0.75,0.85),(1,1),(1.25,1.15),(1.5,1.3),(1.75,1.4),(2,1.5),(2.25\
,1.6) ) )
~
~ |
HHLM HI housing land multiplier i[i] = WITH LOOKUP( LFO Land fraction occupied area i\
[i] , ([(0,0)-(1,4)],(0,2.5),(0.1,2.4),(0.2,2.3),(0.3,2.15),(0.4,2),(0.5,1.8),(0.6,\
1.5),(0.7,1.1),(0.8,0.6),(0.9,0.1),(1,0) ) )
~ Dmnl
~ |
HHM HI housing multiplier i[i] = HHAM HI housing adequacy multiplier[i] * HHLM HI housing land multiplier i\
[i] * HHPM HI housing population multiplier i[i] * HHTM HI housing tax multiplier *\
HHGM HI housing growth factor i[i] * HHLA HI housing location attractiveness i[i] \
* HHSM HI housing social multiplier i[i]
~ Dmnl
~ |
HHO HI housing obsolescence i[i,type] = HH HI housing i[i,type] * Housing Obsolescence Normal\
* HHOM HI housing obsolescence multiplier i[i]
~
~ |
HHOM HI housing obsolescence multiplier i[i] = WITH LOOKUP( ( 1.44 * LN ( MAX ( HHM HI housing multiplier i\
[i] , 0.1245) ) ) , ([(-3,0)-(3,3)],(-3,2.8),(-2,2.6),(-1,2),(0,1),(1,0.5),(2,0.3),\
(3,0.2) ) )
~
~ |
HHPM HI housing population multiplier i[i] = WITH LOOKUP( HRH HI ratio housing i[i] ,\
([(0,0)-(0.1,2)],(0,0.5),(0.02,0.8),(0.04,1),(0.06,1.1),(0.08,1.2),(0.1,1.3) ) )
~
~ |
"HHR HI/housing ratio"[i] = ( SUM ( HI High Income[i,group!,class!] ) + Fraction HI of working population district\
[i] * SUM ( Education Population[i,group!] ) ) / ( SUM ( HH HI housing i[i,type!] )\
* Housing Population Density )
~ Dmnl
~ |
"HHR Housing/HI ratio i"[i] = SUM ( HH HI housing i[i,type!] * Housing Population Density\
) / ( SUM ( HI High Income[i,group!,class!] ) + Fraction HI of working population district\
[i] * SUM ( Education Population[i,group!] ) )
~
~ |
HHSM HI housing social multiplier i[i] = WITH LOOKUP( "HPR HI/population ratio i"[i] \
, ([(0,0)-(0.1,2)],(0,0.3),(0.02,0.7),(0.04,1),(0.06,1.2),(0.08,1.3),(0.1,1.3) ) )
~
~ |
HHT HI housing total = SUM ( HH HI housing i[i!,type!] )
~
~ |
"HMR Housing/MI ratio i"[i] = ( SUM ( MH MI housing i[i,type!] ) * Housing Population Density\
) / ( SUM ( MI Middle Income[i,group!,class!] ) + Fraction MI of working population district\
[i] * SUM ( Education Population[i,group!] ) )
~
~ |
Housing Construction Normal[single] = 0.003 ~~|
Housing Construction Normal[multi] = 0.006
~ Fraction/year
~ |
Housing Obsolescence Normal = 0.0003
~ Fraction/year
```

~ |
Housing Population Density = 2
~ people/housing unit
~ |
HRH HI ratio housing i[i] = 0.2 * SUM (HH HI housing i[i,type!]) / SUM (LH LI housing i\
[i,type!] + MH MI housing i[i,type!])
~~
0.2 is a scaling parameter so that the lookup function operates correctly
|
HUT Housing units total i[i,type] = HH HI housing i[i,type] + MH MI housing i[i,type]\
+ LH LI housing i[i,type]
~ housing units
~ |
HUT Housing units total urban area[type] = SUM (HUT Housing units total i[i!,type])
~
~ |
LFO Land fraction occupied area i[i] = (SUM (HUT Housing units total i[i,type!] * LPH Land per house\
[type!]) + PUT Productive units total i[i] * LPP Land per production unit) / AREA Land i\
[i]
~
~ |
LFO Land fraction occupied urban area = (SUM (HUT Housing units total urban area[type\
!] * LPH Land per house[type!]) + (PUT Productive units total urban area * LPP Land per production unit\
)) / AREA Land total
~
~ |
LFOH Land fraction occupied by housing i[i] = SUM (HUT Housing units total i[i,type!\
] * LPH Land per house[type!]) / AREA Land i[i]
~~
~ :SUPPLEMENTARY
|
LFOHT Land fraction occupied by housing total = SUM (HUT Housing units total urban area\
[type!] * LPH Land per house[type!]) / AREA Land total
~~
~ :SUPPLEMENTARY
|
LFOI Land fraction occupied by industry i[i] = (PUT Productive units total i[i] * LPP Land per production unit\
) / AREA Land i[i]
~~
~ :SUPPLEMENTARY
|
LFOIT Land fraction occupied by industry total = (PUT Productive units total urban area\
* LPP Land per production unit) / AREA Land total
~~
~ :SUPPLEMENTARY
|
LH LI housing i[i,type] = INTEG(MHO MI housing obsolescence i[i,type] - LHD LI housing demolition i\
[i,type] + LHC LI housing construction i[i,type] , LHI LI housing initial i[i,type]\
)
~
~ |
LHAM LI housing abandoned multiplier = WITH LOOKUP("LHR LI/housing ratio" , ([(0,0)-\
(2,4)],(0,3.6),(0.5,2),(1,1),(1.5,0.6),(2,0.4)))
~
~ |
LHAV LI housing assessed value = 0.5
~ thousand euros/housing unit
~ |
LHC LI housing construction i[i,type] = Construction ratio total * LHCD LI housing construction desired i\
[i,type] + LHP LI housing program[i,type]
~
~ |
LHCD LI housing construction desired i[i,type] = LH LI housing i[i,type] * Housing Construction Normal\
[type] * MHM MI housing multiplier i[i]
~
~ |
LHD LI housing demolition i[i,type] = LH LI housing i[i,type] * LHDN LI housing demolition normal\
* LHDM LI housing demolition multiplier i[i] + LHDP LI housing demolition program i\

[i,type]
~ housing units/year
~ |
LHDC LI housing decrease based on favouribility[i] = WITH LOOKUP(AMJZ Accessibility to MI jobs zone i\
[i] / AAMJAZ Average accessibility to MI jobs all zones , ([(0,0)-(2.25,2)],(0,1.3)\
,(0.25,1.3),(0.5,1.2),(0.75,1.1),(1,1),(1.25,0.9),(1.5,0.8),(1.75,0.7),(2,0.6),(2.25\
,0.5)))
~
~ |
LHDM LI housing demolition multiplier i[i] = LHAM LI housing abandoned multiplier * LHLM LI housing land multiplier i\
[i] * LHDC LI housing decrease based on favouribility[i]
~ Dmnl
~ |
LHDN LI housing demolition normal = 0.005
~ Fraction/year
~ |
LHI LI housing initial i[i,single] = 82.7, 912.6, 1480.2, 450.4, 3759.7, 1039.9, 5285.7\
, 6343.3, 823.5, 8454.6, 3804.4, 4978.8, 1642.4, 1592.9 ~~|
LHI LI housing initial i[i,multi] = 8184, 21902.7, 2873.4, 14562.7, 5410.3, 13816, 17695.4\
, 11277, 145.3, 11675.4, 18574.3, 3605.4, 607.4, 784.6
~
~ |
LHLM LI housing land multiplier i[i] = WITH LOOKUP(LFO Land fraction occupied area i\
[i] , ([(0.8,0)-(1,8)],(0.8,1),(0.85,1.2),(0.9,1.6),(0.95,2.2),(1,2.4)))
~ Dmnl
~ |
"LHM LI/housing multiplier i"[i] = WITH LOOKUP("LHR LI/housing ratio i"[i] , ([(0,0)\
-(2,3)],(0,2.5),(0.25,2.4),(0.5,2.2),(0.75,1.7),(1,1),(1.25,0.4),(1.5,0.2),(1.75,0.1\
),(2,0.05)))
~
~ |
"LHM LI/housing multiplier" = WITH LOOKUP("LHR LI/housing ratio" , ([(0,0)-(2,3)],(0\
,2.5),(0.25,2.4),(0.5,2.2),(0.75,1.7),(1,1),(1.25,0.4),(1.5,0.2),(1.75,0.1),(2,0.05\
)))
~
~ |
"LHR LI/housing ratio i"[i] = (SUM (LI Low Income[i,group!,class!]) + Fraction LI of working population district\
[i] * SUM (Education Population[i,group!])) / (SUM (LH LI housing i[i,type!])\
* Housing Population Density)
~
~ |
"LHR LI/housing ratio" = (SUM (LI Low Income[i!,group!,class!]) + Fraction LI of Working Population Total\
* Education Population Total) / (LHT LI housing total * Housing Population Density\
)
~ Dmnl
~ |
LHT LI housing total = SUM (LH LI housing i[i!,type!])
~
~ |
LPH Land per house[single] = 0.017 ~~|
LPH Land per house[multi] = 0.01
~ ha/housing unit
~ |
LPP Land per production unit = 0.05
~ ha/production unit
~ |
MH MI housing i[i,type] = INTEG(HHO HI housing obsolescence i[i,type] + MHC MI housing construction i\
[i,type] - MHO MI housing obsolescence i[i,type] , MHI MI housing initial i[i,type]\
)
~ housing unit
~ |
MHA MI housing average i[i] = INTEG(CMHA Change in MHA[i] , SUM (MH MI housing i[i,\
type!]) * (1 - MHGRI MI housing growth rate initial * MHAT MI housing averaging time\
))
~
~ |
MHAM MI housing adequacy multiplier[i] = WITH LOOKUP("MHR MI/housing ratio"[i] , ([(\
0,0)-(2,3)],(0,0),(0.25,0.05),(0.5,0.1),(0.75,0.3),(1,1),(1.25,1.8),(1.5,2.4),(1.75\

,2.8),(2,3)))
~
~ |
MHAT MI housing averaging time = 10
~ year
~ |
MHC MI housing construction i[i,type] = Construction ratio total * MHCD MI housing construction desired i\
[i,type]
~ housing units/year
~ |
MHCD MI housing construction desired i[i,type] = MH MI housing i[i,type] * Housing Construction Normal\
[type] * MHM MI housing multiplier i[i] + MHCP MI housing construction program i[i,\
type]
~ housing units/year
~ |
MHGM MI housing growth multiplier i[i] = WITH LOOKUP(MHGR MI Housing growth rate[i] \
, ([(-0.1,0)-(0.15,4)],(-0.1,0.8),(-0.05,0.9),(0,1),(0.05,1.1),(0.1,1.2),(0.15,1.3)\
))
~
~ |
MHGR MI Housing growth rate[i] = (SUM (MH MI housing i[i,type!]) - MHA MI housing average i\
[i]) / (SUM (MH MI housing i[i,type!]) * MHAT MI housing averaging time)
~ Fraction/year
~ |
MHGRI MI housing growth rate initial = 0.0045
~
~ |
MHI MI housing initial i[i,single] = 54.6, 463.8, 996.3, 252.9, 2685.5, 567.2, 2686.2\
, 4036.6, 950.2, 7109.6, 1783.3, 4437.7, 1726.6, 1991.2 ~~|
MHI MI housing initial i[i,multi] = 5401.4, 11130.9, 1934, 8175.5, 3864.5, 7536, 8992.8\
, 7176.3, 167.7, 9818, 8706.7, 3213.5, 638.6, 980.719
~
~ |
MHLA MI housing location attractiveness i[i] = WITH LOOKUP(AMJZ Accessibility to MI jobs zone i\
[i] / AAMJAZ Average accessibility to MI jobs all zones , ([(0,0)-(2,2)],(0,0.5),(0.25\
,0.5),(0.5,0.6),(0.75,0.75),(1,1),(1.25,1.25),(1.5,1.4),(1.75,1.5),(2,1.6)))
~
~ |
MHLM MI housing land multiplier i[i] = WITH LOOKUP(LFO Land fraction occupied area i\
[i] , ([(0,0)-(1,4)],(0,2.5),(0.1,2.4),(0.2,2.3),(0.3,2.15),(0.4,2),(0.5,1.8),(0.6,\
1.5),(0.7,1.1),(0.8,0.6),(0.9,0.1),(1,0)))
~
~ |
MHLM MI housing LI multiplier i[i] = WITH LOOKUP("MLR MI/LI ratio housing i"[i] , ([\
(0,0)-(5,2)],(0,0.8),(1,0.9),(2,1),(3,1.1),(4,1.2),(5,1.2)))
~
~ |
MHM MI housing multiplier i[i] = MHAM MI housing adequacy multiplier[i] * MHLM MI housing land multiplier i\
[i] * MHLM MI housing LI multiplier i[i] * MHTM MI housing tax multiplier * MHGM MI housing growth multiplier i\
[i] * MHLA MI housing location attractiveness i[i] * MHSM MI housing social multiplier i\
[i]
~
~ |
MHO MI housing obsolescence i[i,type] = MH MI housing i[i,type] * Housing Obsolescence Normal\
* MHOM MI housing obsolence multiplier i[i]
~
~ |
MHOM MI housing obsolence multiplier i[i] = WITH LOOKUP((1.44 * LN (MAX (MHM MI housing multiplier i\
[i] , 0.1245))) , ([(-3,0)-(3,4)],(-3,2.2),(-2,2),(-1,1.6),(0,1),(1,0.7),(2,0.5),\
(3,0.4)))
~
~ |
"MHR MI/housing ratio"[i] = (SUM (MI Middle Income[i,group!,class!]) + Fraction MI of working population district\
[i] * SUM (Education Population[i,group!])) / (SUM (MH MI housing i[i,type!])\
* Housing Population Density)
~
~ |
MHSM MI housing social multiplier i[i] = WITH LOOKUP("MLR MI/LI ratio"[i] , ([(0,0)-\

(5,2)],(0,0.8),(1,0.9),(2,1),(3,1.1),(4,1.2),(5,1.2)))
~
~ |
MHT MI housing total = SUM (MH MI housing i[i!,type!])
~
~ |
"MLR MI/LI ratio housing i"[i] = (SUM (MH MI housing i[i,type!]) / SUM (LH LI housing i\
[i,type!])) * (2 / 3)
~
~ |
NBC New Business construction i[i,class] = Construction ratio total * NBCD New Business construction desired i\
[i,class]
~
~ |
NBCD New Business construction desired i[i,class] = Business Establishments i[i,class\
] * Business Opening Normal[class] * EM Enterprise multiplier[i] * ELC Enterprise location decision i\
[i,class]
~
~ |
NEA New enterprise average = INTEG(CNEA Change in NEA , SUM (NBC New Business construction i\
[i!,class!]) * (1 - NEGRI New enterprise growth rate initial * NEAT New enterprise averaging time\
))
~ productive unit
~ |
NEAT New enterprise averaging time = 10
~ year
~ |
NEGRI New enterprise growth rate initial = 0.038
~
~ |
PUT Productive units total i[i] = SUM (Business Establishments i[i,class!])
~ productive unit
~ |
PUT Productive units total urban area = SUM (PUT Productive units total i[i!])
~
~ |
TDF Trip distribution function i[i,k] = D Distance i k[i,k] ^ 2
~
~ |
TDFC Trip distribution function construction i[i,k] = D Distance i k[i,k] ^ 3
~
~ |
****
.Legal
**~
|
Citizens[i,group] = INTEG(Naturalization Rate[i,group] + Births[i,group] + Citizens[\
i,group] * Working Population Net Zone Movement[i,group] / SUM (Working Population\
[i,group,class!]) + Total Arrivals[i,group] , Citizens Initial[i,group])
~
~ |
Citizenship Years = 6
~ year
~ = 1 for process and 5 for naturalization period
|
Economic Integration district[i,group] = (Economic Integration HI district[i,group] \
+ Economic Integration MI district[i,group] + Economic Integration LI district[i,group\
]) / 3
~
~ |
Exam Failure Exit Rate[i,group] = (Integration Exam Exit Rate[i,group] + NT2 Exit Rate\
[i,group])
~ Person
~ |
Exemption Rate[i,group] :EXCEPT: [i,refugee] = Exemption Rate constant[i,group] * New Migrants\
[i,group] ~~|
Exemption Rate[i,refugee] = 0
~

```
~ |
Exemption Rate constant[i,group] = MAX ( 1 - Integration Exam Rate constant[i,group] \
- NT2 Rate constant[i,group] , 0)
~
~ |
Immigrant Arrival Rate[i,group] = Immigrant Arrival Rate constant[i,group] * PAT Population Area Total\
[i]
~
~ |
Integration Exam[i,group] :EXCEPT: [i,autochtonen] = INTEG( Integration Exam Rate[i,group\
] - Integration Exam Exit Rate[i,group] - Integration Exam Pass Rate[i,group] + Integration Exam\
[i,group] * Working Population Net Zone Movement[i,group] / SUM ( Working Population\
[i,group,class!] ) , New Migrants[i,group] * Integration Exam Rate constant[i,group\
] ) ~~|
Integration Exam[i,autochtonen] = INTEG( 0, 0)
~
~ |
Integration Exam Exit Rate[i,group] = Integration Exam Exit Rate constant[group] * Integration Exam\
[i,group]
~
~ |
Integration Exam Exit Rate constant[group] = 0.005 / 12
~
~ |
Integration Exam Pass Rate[i,group] = Integration Exam Pass Rate constant[group] * Integration Exam\
[i,group] * Language Ability Multiplier[i] * Ethnic Network Multiplier[i,group] + Language Program Rate\
[group] * Integration Exam Pass Rate constant[group] * IF THEN ELSE ( Time > SWT1 Switch time\
, 1, 0)
~
~ |
Integration Exam Pass Rate constant[group] = 0.615
~
~ |
Integration Exam Rate[i,group] = Integration Exam Rate constant[i,group] * New Migrants\
[i,group]
~
~ |
Integration Exam Rate constant[i,group] = "VO2-VMBO1 Rate constant"[i,group]
~
~ |
Legal Integration district[i,group] :EXCEPT: [i,autochtonen] = ( Permanent Residents[\
i,group] + Naturalization[i,group] + Citizens[i,group] ) / P Population[i,group]
~
~ |
Naturalization[i,group] = INTEG( Permanent Resident Choose to Naturalize[i,group] - Naturalization Rate\
[i,group] + Naturalization[i,group] * Working Population Net Zone Movement[i,group]\
/ SUM ( Working Population[i,group,class!] ) , Permanent Residents[i,group] * Permanent Resident Choose to Naturalize Rate
constant\
[group] )
~
~ |
Naturalization Rate[i,group] = Naturalization[i,group] / Citizenship Years
~
~ |
New Migrants[i,group] = INTEG( Immigrant Arrival Rate[i,group] + Refugee Arrival Rate\
[i,group] - Exemption Rate[i,group] - Integration Exam Rate[i,group] - NT2 Rate[i,group\
] + ( New Migrants[i,group] * Working Population Net Zone Movement[i,group] / SUM (\
Working Population[i,group,class!] ) ) , 0)
~
~ |
NT2[i,group] :EXCEPT: [i,autochtonen] = INTEG( NT2 Rate[i,group] - NT2 Exit Rate[i,group\
] - NT2 Pass Rate[i,group] + NT2[i,group] * Working Population Net Zone Movement[i,\
group] / SUM ( Working Population[i,group,class!] ) , New Migrants[i,group] * NT2 Rate constant\
[i,group] ) ~~|
NT2[i,autochtonen] = INTEG( 0, 0)
~
~ |
NT2 Exit Rate[i,group] = NT2 Exit Rate constant[group] * NT2[i,group]
```

```
~
~ |
NT2 Exit Rate constant[group] = 0.001 / 12
~
~ |
NT2 Pass Rate[i,group] = NT2 Pass Rate constant[group] * NT2[i,group] * Language Ability Multiplier\
[i] * Ethnic Network Multiplier[i,group] + Language Program Rate[group] * NT2 Pass Rate constant\
[group] * IF THEN ELSE ( Time > SWT1 Switch time , 1, 0)
~
~ |
NT2 Pass Rate constant[group] = 0.615
~
~ |
NT2 Rate[i,group] = NT2 Rate constant[i,group] * New Migrants[i,group]
~
~ |
NT2 Rate constant[i,group] = "VO2-HAVO1 Rate constant"[i,group] + "VO2-VWO1 Rate constant"\
[i,group]
~
~ |
Permanent Resident Choose to Naturalize[i,group] = ( Exemption Rate[i,group] + Integration Exam Pass Rate\
[i,group] + NT2 Pass Rate[i,group] ) * Permanent Resident Choose to Naturalize Rate constant\
[group]
~
~ |
Permanent Resident Choose to Naturalize Rate constant[group] = 0.029
~
~ |
Permanent Residents[i,group] :EXCEPT: [i,autochtonen] = INTEG( Exemption Rate[i,group\
] + Integration Exam Pass Rate[i,group] + NT2 Pass Rate[i,group] - Permanent Resident Choose to Naturalize\
[i,group] + Permanent Residents[i,group] * Working Population Net Zone Movement[i,group\
] / SUM ( Working Population[i,group,class!] ) , Permanent Residents Initial[i,group\
] ) ~~|
Permanent Residents[i,autochtonen] = INTEG( 0, 0)
~
~ |
Social Integration district[i,group] = Ratio Dutch Speakers[i,group]
~
~ |
Social Integration Total[group] :EXCEPT: [autochtonen] = SUM ( Ratio Dutch Speakers[i\
!,group] ) / 14 ~~|
Social Integration Total[autochtonen] = 1
~
~ |
********************************************************
.People
********************************************************~
|
Birth Rate[autochtonen] = 0.00291 ~~|
Birth Rate["nw-allochtonen total"] = 0.00513 ~~|
Birth Rate["w-allochtonen total"] = 0.00411
~ Fraction/year
~ |
Birthed Children[i,group] = INTEG( Births[i,group] - Births to Education[i,group] + Birthed Children\
[i,group] * Working Population Net Zone Movement[i,group] / SUM ( Working Population\
[i,group,class!] ) , SUM ( Working Population[i,group,class!] ) * Birth Rate[group]\
* 4)
~
~ |
Births[i,group] = P Population[i,group] * Birth Rate[group]
~ Person/year
~ |
Citizens Initial[i,"nw-allochtonen"] = P Population[i,"nw-allochtonen"] * Second Generation initial\
[i,"nw-allochtonen"] + Permanent Resident Choose to Naturalize Rate constant["nw-allochtonen"\
] * P Population[i,"nw-allochtonen"] ~~|
Citizens Initial[i,"w-allochtonen"] = P Population[i,"w-allochtonen"] * Second Generation initial\
[i,"w-allochtonen"] + Permanent Resident Choose to Naturalize Rate constant["w-allochtonen"\
] * P Population[i,"w-allochtonen"] ~~|
```

```
Citizens Initial[i,refugee] = 0 ~~|
Citizens Initial[i,autochtonen] = P Population[i,autochtonen]
~
~ |
Education Population Total = SUM ( Education Population[i!,group!] + "Youth 14+ Arrivals Not in Education"\
[i!,group!] ) + SUM ( Birthed Children[i!,group!] )
~
~ |
Family Size = 2
~ Person
~ |
Immigrant Arrival Rate constant[i,"nw-allochtonen"] = 0.013 ~~|
Immigrant Arrival Rate constant[i,"w-allochtonen"] = 0.0039 ~~|
Immigrant Arrival Rate constant[i,autochtonen] = 0 ~~|
Immigrant Arrival Rate constant[i,refugee] = 0
~
~ |
Immigrant HI Constant["nw-allochtonen"] = 0.112 ~~|
Immigrant HI Constant["w-allochtonen"] = 0.139 ~~|
Immigrant HI Constant[refugee] = 0 ~~|
Immigrant HI Constant[autochtonen] = 0
~
~ |
Immigrant LI Constant["nw-allochtonen"] = 0.563 ~~|
Immigrant LI Constant["w-allochtonen"] = 0.526 ~~|
Immigrant LI Constant[refugee] = 0 ~~|
Immigrant LI Constant[autochtonen] = 0
~
~ |
Immigrant MI Constant["nw-allochtonen"] = 0.325 ~~|
Immigrant MI Constant["w-allochtonen"] = 0.335 ~~|
Immigrant MI Constant[refugee] = 0 ~~|
Immigrant MI Constant[autochtonen] = 0
~
~ |
P Population[i,group] = SUM ( Working Population[i,group,class!] ) + Education Population\
[i,group] + Birthed Children[i,group]
~
~ |
PAT Population Area Total[i] = SUM ( Working Population[i,group!,class!] ) + SUM ( Education Population\
[i,group!] ) + SUM ( Birthed Children[i,group!] )
~
~ |
PGT Population Group Total[group] = SUM ( Working Population[i!,group,class!] ) + SUM\
( Education Population[i!,group] ) + SUM ( Birthed Children[i!,group] )
~
~ |
PT Population Total = Working Population Total + Education Population Total
~
~ |
RAN Refugee Arrival Normal[i,"nw-allochtonen refugee"] = 8.35 ~~|
RAN Refugee Arrival Normal[i,"w-allochtonen refugee"] = 0.4 ~~|
RAN Refugee Arrival Normal[i,non refugee] = 0
~
~ |
Refugee Arrival Influx[i,group] :EXCEPT: [i,non refugee] = 0 * IF THEN ELSE ( Time > \
SWT1 Switch time , 1, 0) ~~|
Refugee Arrival Influx[i,non refugee] = 0
~
~ |
Refugee Arrival Rate[i,"nw-allochtonen refugee"] = RAN Refugee Arrival Normal[i,"nw-allochtonen refugee"\
] + Refugee Arrival Influx[i,"nw-allochtonen refugee"] ~~|
Refugee Arrival Rate[i,"w-allochtonen refugee"] = RAN Refugee Arrival Normal[i,"w-allochtonen refugee"\
] + Refugee Arrival Influx[i,"w-allochtonen refugee"] ~~|
Refugee Arrival Rate[i,non refugee] = 0
~
~ |
Refugee HI Constant[group] = 0
```

```
~
~ |
Refugee LI Constant["nw-allochtonen refugee"] = 0.675 ~~|
Refugee LI Constant["w-allochtonen refugee"] = 0.665 ~~|
Refugee LI Constant[non refugee] = 0
~
~ |
Refugee MI Constant["nw-allochtonen refugee"] = 0.325 ~~|
Refugee MI Constant["w-allochtonen refugee"] = 0.335 ~~|
Refugee MI Constant[non refugee] = 0
~
~ |
Second Generation[i,group] = INTEG( Births[i,group] + Second Generation[i,group] * ( \
SUM ( MNZM MI net zone movement[i,group,class!] + HNZM HI net zone movement[i,group\
,class!] + LNZM LI net zone movement[i,group,class!] ) - SUM ( HD HI departures[i,group\
,class!] + MD MI departures[i,group,class!] + LD LI departures[i,group,class!] ) ) \
/ SUM ( Working Population[i,group,class!] ) , Second Generation initial[i,group] \
* P Population[i,group] )
~
~ |
Second Generation initial[i,"nw-allochtonen"] = 0.416 ~~|
Second Generation initial[i,"w-allochtonen"] = 0.59 ~~|
Second Generation initial[i,autochtonen] = 0 ~~|
Second Generation initial[i,"w-allochtonen refugee"] = 0 ~~|
Second Generation initial[i,"nw-allochtonen refugee"] = 0
~
~ |
Working Population[i,group,class] = HI High Income[i,group,class] + MI Middle Income[\
i,group,class] + LI Low Income[i,group,class]
~ Person
~ |
Working Population Total = SUM ( Working Population[i!,group!,class!] )
~
~ |
Youth Arrival Rate[i,group] = SUM ( LA LI arrivals[i,group,class!] + MA MI arrivals[i\
,group,class!] + HA HI arrivals[i,group,class!] ) * Youth Arrival Rate constant[group\
]
~
~ |
Youth Arrival Rate constant[non refugee] = 0.2 ~~|
Youth Arrival Rate constant[refugee] = 0.25
~
~ |
********************************************************
.Social
********************************************************~
|
Cognitive Dissonance[i,group] = WITH LOOKUP( Ratio Group by Area[i,group] , ([(0,0)-(\
1,1)],(0,1),(1,0) ) )
~
~ |
Cognitive Dissonance Average[group] = SUM ( Cognitive Dissonance[i!,group] ) / 14
~
~ |
Cognitive Dissonance compared to average[i,group] = ( Cognitive Dissonance[i,group] /\
Cognitive Dissonance Average[group] )
~
~ |
Cognitive Dissonance Multiplier[i,group] = WITH LOOKUP( Cognitive Dissonance compared to average\
[i,group] , ([(0,0)-(1,2)],(0,0.5),(1,1.5) ) )
~
~ |
Dutch Speakers[i,group] :EXCEPT: [i,autochtonen], [i,refugee] = INTEG( "P8-PRO/VSO1"[\
i,group] + "P8-VO1"[i,group] + Integration Exam Pass Rate[i,group] + NT2 Pass Rate[\
i,group] + Exemption Rate[i,group] + Dutch Speakers[i,group] * ( Working Population Net Zone Movement\
[i,group] / SUM ( Working Population[i,group,class!] ) ) + Total Arrivals[i,group] \
, P Population[i,group] - Immigrant Arrival Rate[i,group] ) ~~|
Dutch Speakers[i,autochtonen] = 1 ~~|
```

Dutch Speakers[i,refugee] = INTEG("P8-PRO/VSO1"[i,refugee] + "P8-VO1"[i,refugee] + Integration Exam Pass Rate\
[i,refugee] + NT2 Pass Rate[i,refugee] + Exemption Rate[i,refugee] + Dutch Speakers\
[i,refugee] * (Working Population Net Zone Movement[i,refugee] / SUM (Working Population\
[i,refugee,class!])) + Total Arrivals[i,refugee] , 0)
~
~ |
Economic Integration HI[group] = (Fraction Group HI of Group Working Population[group\
] / Fraction Group HI of Group Working Population[autochtonen])
~
~ |
Economic Integration HI district[i,group] = Fraction Group HI in district of Group Total\
[i,group] / Fraction Group HI in district of Group Total[i,autochtonen]
~
~ |
Economic Integration LI[group] = (Fraction Group LI of Group Working Population[group\
] / Fraction Group LI of Group Working Population[autochtonen])
~
~ |
Economic Integration LI district[i,group] = Fraction Group LI in district of Group Total\
[i,group] / Fraction Group LI in district of Group Total[i,autochtonen]
~
~ |
Economic Integration MI[group] = (Fraction Group MI of Group Working Population[group\
] / Fraction Group MI of Group Working Population[autochtonen])
~
~ |
Economic Integration MI district[i,group] = Fraction Group MI in district of Group Total\
[i,group] / Fraction Group MI in district of Group Total[i,autochtonen]
~
~ |
Economic Tension HI Average = SUM (Economic Tension HI zone i[i!]) / 14
~
~ |
Economic Tension HI i compared to average[i] = (Economic Tension HI zone i[i] / Economic Tension HI Average\
)
~
~ |
Economic Tension HI zone i[i] = WITH LOOKUP(Fraction HI of working population district\
[i] , ([(0,0)-(1,1)],(0,1),(1,0)))
~~
Average of two measures
|
Economic Tension LI Average = SUM (Economic Tension LI zone i[i!]) / 14
~
~ |
Economic Tension LI i compared to average[i] = (Economic Tension LI zone i[i] / Economic Tension LI Average\
)
~
~ |
Economic Tension LI zone i[i] = WITH LOOKUP(Fraction LI of working population district\
[i] , ([(0,0)-(1,1)],(0,1),(1,0)))
~~
Average of two measures
|
Economic Tension MI Average = SUM (Economic Tension MI zone i[i!]) / 14
~
~ |
Economic Tension MI i compared to average[i] = (Economic Tension MI zone i[i] / Economic Tension MI Average\
)
~
~ |
Economic Tension MI zone i[i] = WITH LOOKUP(Fraction MI of working population district\
[i] , ([(0,0)-(1,1)],(0,1),(1,0)))
~~
Average of the two measures
|
Ethnic Network Multiplier[i,group] :EXCEPT: [i,autochtonen] = WITH LOOKUP(Ratio Group by Area\
[i,group] , ([(0,0)-(1,2)],(0,1),(1,0.6666))) ~~|

```
Ethnic Network Multiplier[i,autochtonen] = 1
~
~ |
Fraction Group HI in district of Group Total[i,group] = SUM ( HI High Income[i,group,\
class!] ) / SUM ( Working Population[i,group,class!] )
~
~ |
Fraction Group HI of Group Working Population[group] = SUM ( HI High Income[i!,group,\
class!] ) / SUM ( Working Population[i!,group,class!] )
~
~ |
Fraction Group LI in district of Group Total[i,group] = SUM ( LI Low Income[i,group,class\
!] ) / SUM ( Working Population[i,group,class!] )
~
~ |
Fraction Group LI of Group Working Population[group] = SUM ( LI Low Income[i!,group,class\
!] ) / SUM ( Working Population[i!,group,class!] )
~
~ |
Fraction Group MI in district of Group Total[i,group] = SUM ( MI Middle Income[i,group\
,class!] ) / SUM ( Working Population[i,group,class!] )
~
~ |
Fraction Group MI of Group Working Population[group] = SUM ( MI Middle Income[i!,group\
,class!] ) / SUM ( Working Population[i!,group,class!] )
~
~ |
Fraction HI of working population district[i] = SUM ( HI High Income[i,group!,class!]\
) / SUM ( Working Population[i,group!,class!] )
~
~ |
Fraction HI of Working Population Total = SUM ( HC HI class[class!] ) / Working Population Total
~
~ |
Fraction LI of working population district[i] = SUM ( LI Low Income[i,group!,class!] \
) / SUM ( Working Population[i,group!,class!] )
~
~ |
Fraction LI of Working Population Total = SUM ( LC LI class[class!] ) / Working Population Total
~
~ |
Fraction MI of working population district[i] = SUM ( MI Middle Income[i,group!,class\
!] ) / SUM ( Working Population[i,group!,class!] )
~
~ |
Fraction MI of Working Population Total = SUM ( MC MI class[class!] ) / Working Population Total
~
~ |
Language Ability Multiplier[i] = WITH LOOKUP( Ratio Dutch Speakers District[i] , ([(0\
,0)-(1,2)],(0,0),(0.250765,0.0570175),(0.46789,0.179825),(0.611621,0.399123),(0.669725\
,0.587719),(0.733945,0.95),(0.785933,1.07),(0.877676,1.153),(1,1.2) ) )
~
~ |
Language Labor Multiplier[i,group] :EXCEPT: [i,autochtonen] = WITH LOOKUP( Ratio Dutch Speakers\
[i,group] , ([(0,0)-(1,2)],(0,0),(0.250765,0.0570175),(0.46789,0.179825),(0.611621,\
0.399123),(0.669725,0.587719),(0.733945,0.95),(0.785933,1.07),(0.877676,1.153),(1,1.2\
) ) ) ~~|
Language Labor Multiplier[i,autochtonen] = 1
~
~ |
Legal Integration Total["nw-allochtonen total"] = SUM ( Permanent Residents[i!,"nw-allochtonen total"\
!] + Naturalization[i!,"nw-allochtonen total"!] + Citizens[i!,"nw-allochtonen total"\
!] ) / SUM ( PGT Population Group Total["nw-allochtonen total"!] ) ~~|
Legal Integration Total["w-allochtonen total"] = SUM ( Permanent Residents[i!,"w-allochtonen total"\
!] + Naturalization[i!,"w-allochtonen total"!] + Citizens[i!,"w-allochtonen total"!\
] ) / SUM ( PGT Population Group Total["w-allochtonen total"!] ) ~~|
Legal Integration Total[autochtonen] = 1
~
```

```
~ |
Permanent Residents Initial[i,group] :EXCEPT: [i,autochtonen], [i,refugee] = P Population\
[i,group] * 0.25 ~~|
Permanent Residents Initial[i,refugee] = 0 ~~|
Permanent Residents Initial[i,autochtonen] = 0
~
~ |
Ratio Citizens[i,group] :EXCEPT: [i,autochtonen] = Citizens[i,group] / P Population[i\
,group] ~~|
Ratio Citizens[i,autochtonen] = 1
~
~ |
Ratio Dutch Speakers[i,"nw-allochtonen total"] = Dutch Speakers[i,"nw-allochtonen total"\
] / P Population[i,"nw-allochtonen total"] ~~|
Ratio Dutch Speakers[i,"w-allochtonen total"] = Dutch Speakers[i,"w-allochtonen total"\
] / P Population[i,"w-allochtonen total"] ~~|
Ratio Dutch Speakers[i,autochtonen] = 1
~
~ |
Ratio Dutch Speakers District[i] = SUM ( Dutch Speakers[i,group!] ) / PAT Population Area Total\
[i]
~
~ |
Ratio Group by Area[i,autochtonen] = ( P Population[i,autochtonen] ) / PAT Population Area Total\
[i] ~~|
Ratio Group by Area[i,"nw-allochtonen total"] = ( P Population[i,"nw-allochtonen"] + \
P Population[i,"nw-allochtonen refugee"] ) / PAT Population Area Total[i] ~~|
Ratio Group by Area[i,"w-allochtonen total"] = ( P Population[i,"w-allochtonen"] + P Population\
[i,"w-allochtonen refugee"] ) / PAT Population Area Total[i]
~
~ |
Ratio Permanent Residents[i,group] :EXCEPT: [i,autochtonen] = ( Permanent Residents[i\
,group] ) / P Population[i,group] ~~|
Ratio Permanent Residents[i,autochtonen] = 0
~
~ |
Ratio Refugees[i,"nw-allochtonen total"] = P Population[i,"nw-allochtonen refugee"] /\
P Population[i,"nw-allochtonen"] ~~|
Ratio Refugees[i,"w-allochtonen total"] = P Population[i,"w-allochtonen refugee"] / P Population\
[i,"w-allochtonen"]
~
~ |
```

Appendix C: Storyboard

Refugees in Urban Environments: Social, Economic, and Infrastructure Impacts

Future Operations Investigation Laboratory

Problem Statement

The United Nations High Commissioner for Refugees (UNHCR) has estimated that in 2015 there were 21.3 million refugees worldwide; it is estimated that 1.8 million of these persons were newly displaced during 2015. It is estimated that 60% of refugees live in urban areas. The impact of this flow on cities and on the refugees, themselves, is not fully understood.

Research Questions

- Which factors are the drivers of integration in a city system?
- What are the effects of changing assumptions on city system behavior?
- Which government policies are best suited to address problems with integration?

Methodology Framework

- Extension of Sanders and Sanders (2004) spatial urban dynamics model with additional subsystem structures.
- Specification of model to the city of Rotterdam, the Netherlands using Dutch Central Bureau of Statistics (CBS) databases.
- Sensitivity analysis of model quantitative and qualitative results by subjective parameters to uncertainty.
- Policy impact experiments using government programs aimed at addressing social, legal, and economic integration of refugees.

Software Utilized

- Vensim PRO: SD modeling and visualization
- Excel: data manipulation
- JMP: experiment design matrix, ANOVA

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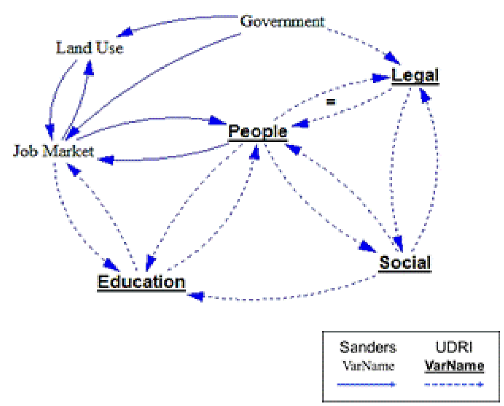
Urban Dynamics Refugee Integration (UDRI) model



Subscript	Meaning	Elements
i (k)	District	*D1, D2, ... , D13, D14*
group	Ethnic group	*autochtonen, w-allochtonen, nw-allochtonen, w-allochtonen refugee, nw-allochtonen refugee*
class	Economic activity (SBI 2008)	*A, B-F, G+I, H+J, K-L, M-N, R-U*
type	Housing unit structure	*single, multi*

Model Description

- Representation of the city of Rotterdam, the Netherlands and its 14 districts from 2007 to 2044.
- The UDRI model subsystems represent…
  - Land Use: buildings within the city and the land they occupy.
  - Job Market: individuals in the working population.
  - Government: policy programs
  - People: aggregation of all people in the model system
  - Legal: Dutch immigrant integration process
  - Education: Dutch education system (primary thru tertiary)
  - Social: measures of integration and social influence variables

Significance of Research

- Insight into urban dynamics when affected by influx of new persons, specifically refugees
- Recommended focus on language training and job training programs to improve measures of integration for refugees.
- The UDRI model is a valid representation of a large Dutch city which can be used for policy experimentation and analysis.

Future Work

- Exploration of refugee placement policy impact (e.g., dispersal versus laissez faire).
- Implementation of transportation infrastructure into UDRI model.
- Expansion of UDRI model using gender and emotional variables to capture additional dynamics.

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14. ABSTRACT

The United Nations High Commissioner for Refugees has estimated that in 2015 there were 21.3 million refugees worldwide; it is estimated that 1.8 million of these persons were newly displaced during 2015. As refugees leave their country to seek the protection of another nation's government, they generally flow into urban areas. The impact of this flow on cities and on the refugees, themselves, is not fully understood. This study is focused on the impact of government policy decisions on the social, legal, and economic integration of refugees within an urban environment. Investigation into this topic resulted in the development of a system dynamics model representing the city of Rotterdam, the Netherlands. The results of a designed experiment on the model indicate that economic policy directed towards refugees or specific ethnic groups results in positive trends of integration within a city system. This pilot study provides insight into the impacts of refugee flow and policy decisions within the applied context of an urban model.

15. SUBJECT TERMS

system dynamics, urban dynamics, refugees, city, integration, Rotterdam, the Netherlands

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