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Subsidy policy and its effect on social housing acquisition in San Luis Potosi, Mexico

Política de subsidios y su efecto en la adquisición de vivienda social en San Luis Potosí, México

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Abstract: Since the 1970s, the social housing sector in Latin America underwent market-led transformations that reduced State intervention and boosted participation by private developers and financial institutions. Their participation increased the housing supply but left behind the poorest sectors of the population for whom this type of housing remains unaffordable. Subsidy policies seek to promote affordability, either by directly providing workers with down payment funds or by injecting money into the production chain to reduce housing prices. Their implementation, however, remains marginal and shows a downward trend while housing costs steadily continue to rise. Even if subsidies are central to remedying the affordability gap left by market-led social housing policies in Latin America, few studies include them as a variable that would help understand the social housing production cycle and project potential scenarios. This study applies a dynamic model to simulate three prospective scenarios that analyze the relationship between subsidy provision and housing deficit reduction in the Metropolitan Area of San Luis Potosi, Mexico. The results show that the best-case scenario is one where subsidies are increased by 30% to reduce the housing deficit while avoiding skyrocketing land prices and housing costs.

Keywords: Dynamic model, housing affordability, housing market, Metropolitan Area of San Luis Potosi, system dynamics

Resumen: *Desde la década de 1970, el sector de la vivienda social en Latinoamérica sufrió transformaciones que redujeron la intervención del Estado e incrementaron la participación de desarrolladores privados e instituciones financieras. Esto multiplicó la oferta, pero dejó atrás a los sectores más pobres de la población para quienes este tipo de vivienda sigue siendo inasequible. Las políticas de subsidios buscan promover la asequibilidad de la vivienda, ya sea dotando directamente a los trabajadores de fondos para pagar el enganche de una hipoteca o inyectándole dinero a la cadena de producción para reducir el costo final de la vivienda. Su implementación, sin embargo, es marginal y muestra una tendencia a la baja mientras que los costos se incrementan constantemente. Aún y cuando los subsidios son centrales para atender la brecha de asequibilidad que dejan las políticas de mercado en Latinoamérica, pocos estudios los incluyen como variable para entender el ciclo de producción de la vivienda social y para proyectar escenarios posibles. Este estudio implementa un modelo dinámico a la simulación de tres escenarios prospectivos que analizan la relación entre provisión de subsidios y la reducción del déficit de vivienda en el Área Metropolitana de San Luis Potosí, México. Los resultados muestran que el mejor escenario para reducir el déficit y evitar un incremento abrupto en los precios del suelo y en el costo final de la vivienda consiste en incrementar los subsidios en un 30 %.*

Palabras clave: *Modelo dinámico, vivienda asequible, mercado de vivienda, Área Metropolitana de San Luis Potosí, dinámica de sistemas*

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Introduction

Since the 1970s, changes in the social housing sector in Latin America have been moved by economic paradigms that led the state to retreat and become a facilitator of growth rather than a direct promoter, "supporting market demand, instead of directly providing housing supply" (Rolnik, 2012, p. 3)[1]. Along these lines, the state restructured its institutions and set the conditions for the market to regulate offer and demand, enacting less stringent legislation and public policy that favors developers, promoting public-private partnerships, setting in place new financing schemes, and enfolding local housing markets into the global economy (Hidalgo Dattwyler et al., 2021; Puebla, 2002; Rolnik, 2012). Under this new scheme, housing became a financial product, a private responsibility and not a public one, and an opportunity to support the construction sector (Hidalgo Dattwyler et al., 2021). Furthermore, rising construction and land prices impact final housing costs and leave behind the large working-class sector that earns low wages. Social housing refers to a system that promotes the acquisition of finished housing for the working sector in urbanized units.

For this financial product to be affordable for the working class and massively consumed, a triad of mechanisms was set in place: savings, subsidies, and debt[2]. Savings are a mechanism to accumulate capital for a down payment. This responsibility is fulfilled by employees through savings accumulated directly from their paycheck and employers through contributions towards their workers´ housing funds (Jaramillo y Schteingart 1983). Debt is a strategy workers use to fill the gap between rising housing prices and low wages. According to Hidalgo Dattwyler et al. (2022), debt works as an "exploitation mechanism that extracts value from domestic economies" (p. 8). Moreover, subsidies act as a publicly financed guarantee that backs up the blue-collar sectors of the population's spending capacity. This, in turn, decreases financial institutions' lending risks and developers' investment risks while busting the housing production economy. Therefore, it is "one of the most important governmental tools to promote and materialize property" (Hidalgo Dattwyler et al., 2022, p. 13).

Subsidies, credit from banking institutions, and microcredits are common strategies for producing and granting the poor access to social housing in many countries (Rolnik, 2012). However, while some countries subsidize the construction process to reduce final housing costs (Malmir & Spicar, 2015), in Latin America, subsidizing housing demand is more common. In Mexico, subsidies for housing acquisition are typically demand-oriented and target people who earn up to 2.6 times the minimum wage. They cover between 10 and 25 % of the housing price, depending on the beneficiary's income and the housing cost (Merchand, 2017). INFONAVIT[3], the public institution that finances 80 % of the social housing stock in the country, subsidized 13,000 units in 2022.

In the metropolitan area of San Luis Potosi (MASLP), where this case study was conducted, the local Instituto de Vivienda de San Luis Potosi, (2022) administered 1,358 subsidies in 2020. This represents 14% of total social housing acquired in that year, and the trend for the last ten years is going downwards.

1. The translation of the quote from Rolnik (2012) was made by the authors.
2. According to Rodríguez and Sugranyes (2011), this triad of mechanisms was crafted by the "Chicago Boys" and first implemented in Chile.
3. National Workers' Housing Institute (Instituto Nacional de Vivienda para los Trabajadores).

The housing deficit, however, reached 4,320 units (Parra et al., 2022), while the population grew steadily by 1.5 % per year (Ayuntamiento de San Luis Potosí, 2020). The MASLP is in the north-central region of Mexico, located in one of the most significant industrial corridors in the country: 78.10 % of the national GDP is concentrated within a 500-km radius of the MASLP (López, 2021). In the last decade, the MASLP has experienced accelerated growth due to the expansion of the automotive industry. By 2020, this industry had generated 82,000 formal jobs in the region, attracting workers from neighboring states and increasing the demand for employment and housing (Parra et al., 2022).

Population growth and housing needs promoted the proliferation of peripheral social housing developments where land is cheaper, contributing to the rapid expansion of the MASLP. According to Alva and Martínez (2018), the MASLP grows annually at 3.5 % (Alva y Martínez, 2018). As of 2020, only 2,795 hectares of interurban land were available, positioning the real estate market as one of the most expensive in the country (Camara Mexicana de la Industria de la Construccion [CMIC], 2020). Land scarcity in a context where the State has no land reserves for housing and a few large developers monopolize land sent land values soaring to a point where building centrally located social housing became an unviable business (Amuzurrutia et al., 2015).

The effects of COVID-19 on the economy have decelerated the flow of direct foreign investment in the MASLP. Real estate values skyrocketed, and families´ acquisition capacity dropped. Therefore, global and local factors are key in understanding the behavior of the social housing production cycle and the effects of subsidy policies on acquisition and prices. Even if subsidies are central to resolving the affordability gap left by market-led social housing policies in Latin America and many other parts of the world, few studies include them as a variable to understand the social housing production cycle. This study addresses this gap and applies a dynamic model to simulate three prospective scenarios that analyze the relationship between subsidy provision and housing deficit reduction in the Metropolitan Area of San Luis Potosi, Mexico.

The model design, calibration methods, and variable selection of this work are based on dynamic models applied in similar studies in different parts of the world (Barlas et al., 2007; Eskinasi, 2014; Kapourani & Kapmeier, 2017; Malmir & Spicar, 2015; Suprun, et al., 2018). However, unlike other authors, the study undertakes an integral analysis and discussion of variables instead of breaking them into loops. The study builds on previous work published by the authors (Parra et al., 2022) but focuses specifically on subsidies, a research gap identified in the 2022 publication. Based on this, the model includes the price per square meter of land as one of the variables that drive the social housing construction cycle. We hypothesize that even if the public sector invested in subsidy policies to promote the housing offer and meet an increasing need, rising land prices and housing production costs discourage production and render acquisition unaffordable. Therefore, subsidy policies must be coupled with other planning strategies and alternative modes of housing production to meet the needs of the working sector.

The article develops the analyses in six sections. The first section briefly presents the background, including the main housing policy changes in Latin America in recent decades and subsidy programs in Mexico. The second section presents a literature review and identifies the work most relevant to this study; the third section explains the methods used to design and run the dynamic model, and the fourth section describes the results. Sections five and six present the discussion and conclusions, respectively.

Background: Housing and subsidy policies in Latin America and Mexico

The market-led transformations that the social housing sector underwent in Latin American countries in the 1970s led to the implementation of an unsustainable housing production model that caused a bust in the construction sector. As a result, starting in the 1990s and more intensively in the 2000s, Mexico experienced an unprecedented period of social housing construction that collapsed in 2009 when the model's externalities came up against the economic crisis. In Chile, where the model was first implemented, it brought sustained housing growth between 1980 and 2006, similar to the European post-war era (Rodríguez y Sugranyes, 2011).

The model relies on the construction of massive developments in inexpensive peripheral land. This maximizes profit and allows economies of scale to reduce unit construction costs. This, in turn, reduces housing prices while fulfilling a pressing housing need. The strategy, however, fostered the implementation of predatory practices by large developers who secured extensive land reserves (Salas, 2002). This promoted speculation and land scarcity, a rise in land values, and, as a result, in housing prices, leaving the poorest sectors behind (Rodríguez y Sugranyes, 2011; Rolnik, 2012).

In addition to these problems, building massive social housing developments in the peripheries led to other urban and environmental problems, such as urban sprawl (Marengo y Elorza, 2016), land consumption, and increased pendular movement (Hidalgo Dattwyler et al., 2022; Monkkonen, 2011). Expelling the working class to the periphery promotes segregation and social exclusion (Münzenmayer, 2018) and deprives families of proximity to job opportunities (Hidalgo Dattwyler et al., 2021). Additionally, while housing construction by the private sector is fast, facility provision by the public sector is very slow, resulting in poorly served developments that lack schools, health, sports, and community facilities (Olivera, 2018). Rodríguez and Sugranyes (2011) called this phenomenon propertied poverty, highlighting the paradox that results from poorly designed policies that fulfill housing production quotas but reproduce social and urban problems. These problems led many residents to abandon their properties. In a recent study, Melgarejo-Ochoa and Cuevas-Rodríguez (2021) found that long distances to jobs, schools, and public services and the time and resources invested in commuting are the leading causes of abandonment. These conditions, coupled with mortgage failure due to the 2009 financial crisis, led to a quarter of the social housing stock built between 2006 and 2009 in Mexico being abandoned (Torres, 2013).

In this context of the crisis, the first subsidy programs were implemented by INFONAVIT in Mexico in 2007, one year after Chile (Hidalgo Dattwyler et al., 2021). The aim of the programs was twofold: on the one hand, to fill a market gap that left behind workers from the lowest income brackets by complementing their low-paying capacity with funds directly invested in housing acquisition, and on the other, subsidies were used as government tools to direct urban development and promote green technologies.

Tu Casa, for example, is a subsidy program that targets the poorest sectors of the population. Salazar et al. (2015) analyzed the implementation of this program in Zacatecas and found that it has reached 1.3 % of the total population, most of whom earn below three minimum wages (amongst the poorest sectors of the population). Beneficiaries are satisfied with the program mainly because it enabled them to acquire a house but report that the dwelling size is under-normed and that their access to jobs and services did not improve compared to their previous residence. Hernández & Ordoñez (2009) analyzed the implementation of the same program in Tijuana and concluded that the areas where these housing complexes are located lack accessibility and adequate infrastructure.

One of the largest subsidy programs, Hipoteca Verde, evaluates developments' location, units' green technologies, and building typologies. The beneficiaries who acquire a house in the developments are evaluated as having the best access to larger subsidies. In other words, the policy seeks to impact developers' decisions to build central, compact, well-served social housing developments in exchange for an increased demand encouraged by access to larger subsidies, thus containing expansion, promoting verticalization, and improving quality of life. In sum, the subsidy policy seeks to "spatially direct mortgage management" (Garcia, 2010 in Hidalgo Dattwyler et al., 2021, p. 13) while encouraging a sustained production of housing units.

Subsidy policy has, however, been largely criticized, and its contribution to mitigating the problems it addresses (i.e., to attend to the housing needs of the poorest sectors and promote sustainable urban development) remains marginal. At a structural level, these problems result from predatory neoliberal practices that must be addressed through regulatory, policy, and planning changes (Hidalgo Dattwyler et al., 2022). At a policy design and implementation level, subsidies are failing to match adequate job opportunities, public facilities, and services to new developments (Hidalgo Dattwyler et al., 2021), and their support to the poorest sectors is very limited and shows a downward trend.

Literature review: System dynamics and housing policies

Housing subsidy policies are broadly implemented in many countries. However, their effectiveness in benefiting the poorest sectors is still under evaluation, especially in contexts such as Mexico, where a large percentage of the population works in the informal sector (Salas, 2002). Furthermore, the state invests large amounts of public funds in subsidies, infrastructure, and services to support builders and financial institutions. However, housing scarcity and housing abandonment are still persistent problems. To analyze them, many studies have implemented a system dynamics methodology to project variables into the future, explore different scenarios, and forecast possible outcomes (Malmir, & Spicar, 2015).

Jay W. Forrester first developed system dynamics in the mid-1950s to understand and predict managerial problems in large industrial companies. In 1968, Forrester and Collins began to apply system dynamics to study urban environments to test public policy implementation in American cities (Forrester, 2007). They found that public policy implementation often yielded paradoxical results and used the methodology to test alternative policy scenarios and forecast outcomes that support decision-makers. Dynamic models facilitate the analysis of complex social problems through conceptual and mathematical models (Blanco, 2010). Constructing these models requires a systematic process: first, the system is described, then its elements and their relationships are conceptually and mathematically represented in a model. Finally, variable behavior is simulated through time (Suprun et al., 2018).

Contemporary research has implemented system dynamics in studies focused on real estate markets, urban planning, and public policy worldwide. Within the planning field, the most common topics found in the literature were land use changes and urban expansion. For example, Supriatnaa et al. (2016) modeled urban sprawl and future land demand in the Cimandiry estuary, Indonesia. Shen et al. (2009) used the same methodology to analyze future urban expansion in Hong Kong. The model integrated demographic, housing, transportation, and land availability variables. The authors projected 40-year scenarios and explored the sprawl limits and environmental impacts of Hong Kong's future development. Nieto et al. (2016) built scenarios in Latin America to identify trends and project land use changes in San Juan, Argentina. This model integrated interacting parameters such as the city's population, green surfaces, the number of homes, and their variation. Their results were used to propose high-density policies and thus reduce urban expansion rates.

Studies commonly focus on the factors that impact housing demand, supply, and prices within housing policies and real estate markets. In Europe, for example, Eskinasi (2014) analyzed post-war housing policies in the Netherlands, and Barlas et al. (2007) built a dynamic model to simulate and understand housing price fluctuations in Istanbul. Kapourani and Kapmeier (2017) constructed scenarios to assess the effects of industrial investment on the real estate sector in the Stuttgart region.

In China, Zhang (2018) applied the same technique to understand the effects of urban policy implementation on the real estate market in several Chinese cities. Hashim et al. (2018) studied the factors that cause housing price increases in Malaysia's real estate market. Through a cyclical dynamic model, they concluded that the rise in real estate prices is caused by the accelerated rate of population growth, the shortage of housing stock, and inflation. The authors propose intervention policies to control a future bubble in the local real estate market. In the same country, Nazihah and Nazifa (2022) applied system dynamics to understand the future effects of the unsold housing stock in Penang. Their study focused on three variables: housing demand, supply, and price. The authors propose housing schemes with more payment facilities to support housing acquisition.

In the US, Murphy (2018) studied the forces driving housing demand in San Francisco Bay. Jiang (2017) used system dynamics to analyze the US governmental policies to combat family homelessness in Fort Collins, Colorado. This model's structure includes population, housing, supply, demand, housing price, and governmental intervention variables. The author concludes that the voucher policy for low-income families has been the most successful at combating homelessness. Based on these results, the author proposes reforms to streamline bureaucratic procedures and improve the program's operating rules.

Dynamic modeling is a methodology commonly used in urban and housing studies; nonetheless, few studies have been found in the literature review that address housing subsidy policies. Malmir and Spicar (2015) built a dynamic model and estimated the effects of subsidies on Tehran's social housing market. The model's main structure included inflation, housing prices, GDP, housing subsidies, land availability, construction costs, and population. In Iran, subsidies are given to developers to cover part of construction costs, aiming to reduce housing price inflation. However, the results of the application of this policy are adverse since developers used the subsidies in their favor, inflating housing prices until they became unaffordable for the working class, which promoted the migration of this population sector. As a result, after analyzing several hypothetical scenarios, the authors recommend a 30 % decrease in the annual number of subsidies to control housing prices.

In Taichung City, Taiwan, the housing market achieved weak growth, investment in the sector meant high risks, real estate projects became expensive, and the amount of subsidized housing began to be practically irrelevant. Ho et al. (2012) used systems dynamics to simulate the hypothetical application of a financial strategy that included government subsidies, developer tax incentives, and loans with low interest rates to depress the housing sector. In this case, the scenarios demonstrated that increasing these three factors increases the number of first-time homebuyers, and developers are encouraged to invest in the market.

In Latin America, subsidies were only included as a dynamic model variable in two Colombian studies, and none were found in Mexico. The two Colombian studies relate housing prices increase to urban informality. Subsidies, in this context (as opposed to the Iranian case that targets developers), are provided directly to social housing beneficiaries to promote formal housing acquisition. Baena and Olaya (2013) designed a dynamic model to identify causal cycles that relate different variables, including housing cycle variables (e.g., land and housing prices, housing quality) and demographic variables (e.g., EAP) to various actors' levels of participation. In line with the model's results, the authors propose policy changes to reduce the housing deficit, such as community programs for neighborhood improvement supported by subsidy programs for progressive building. The authors also identify the impact of land values on affordable housing access and propose that a social housing quota be implemented in new developments.

Blanco (2010) also analyzed urban informality and its relationship with the subsidy policy in Bogota (regionally recognized for its informality rates). He simulated scenarios that indicate that subsidies have increased acquisition only marginally since housing continues to be very expensive and is in peripheral areas far from infrastructure, services, and urban facilities. As a result, he suggests that in addition to subsidy policies, the areas where social housing is developed need to be targeted and invested in by public programs and private developers to improve urban infrastructure and services.

In sum, subsidy policies are needed in financial systems where wages increase much slower than land values, making housing unaffordable for the working class. Subsidies fill the income gap that the working class needs to access housing. The implementation of subsidy policies, however, needs to be carefully designed to avoid triggering other problems, such as housing price inflation, as found in Iran (Malmir & Spicar, 2015). Furthermore, and in line with Ho et al. (2012) and Blanco (2010), these policies need to be coupled with other financial and territorial strategies to improve people's quality of life and avoid further promoting the production of peripheral and segregated housing.

In relation to dynamic modeling, the studies share design similarities. Their structure is cyclical, and they are usually composed of two or more feedback loops. The set of variables that make them up is similar, but the simulations vary depending on the study. Certain studies focus on variables that affect housing prices (Murphy, 2018; Zhang, 2018). Others highlight the supply-demand disparity and land hyperinflation (Hashim et al., 2018; Nazihah & Nazifa, 2022). A small number of these studies analyze the effect of subsidies on housing demand (Blanco, 2010). In all these cases, the analyses are carried out by subsystems.

The cases studied show that system dynamics and scenario building are valuable tools for analyzing public policies. Policy outcomes can be evaluated by estimating hypothetical futures to inform their design and operating rules. Dynamic models can serve as information management tools to generate effective and efficient proposals tailored to the needs of target populations.

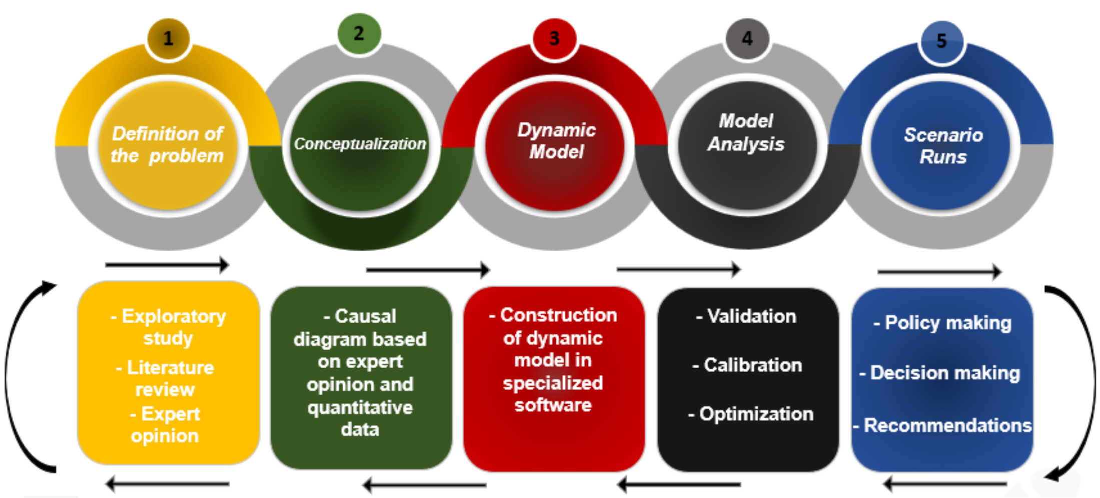
Methodology

This research presents a dynamic model to understand the relationship between housing deficit, prices, costs, and subsidies for social housing acquisition. The research explores three scenarios projected for 2040. We used semi-structured interviews with experts in social housing developments and urban agenda projects to collect primary data. We collected socioeconomic and territorial data for San Luis Potosí from official, national, and state sources for 2010, 2015, and 2020 (Gaytán et al., 2017). We used Vensim PLE x64, SPSS, and Microsoft Excel for model construction and applied regression and correlation techniques for data analysis, model calibration, and scenario estimation (Gandara, & Osorio, 2014). In dynamic models, similarity is calculated statistically; no longitudinal studies were found that contrast data estimated from prospective scenarios with data collected from the real system.

Figure (1) shows that the modeling process is divided into five stages with specific activities (Suprun et al., 2018). The methodological strategy, variable sets, and main model structure are based on Parra et al. (2022). The modeling process is based on Dipasquale and Wheaton (1992). These authors constructed a model that has become the basis of most contemporary housing studies that apply system dynamics. It consists of a main structure subdivided into 1) acquired housing, 2) available housing, and 3) estimated housing demand. These indicators represent the model's main cyclical structure and correlate with economic and demographic variables such as land value, subsidies, interest rates, demand elasticity, and population.

Figure 1

Modeling process



Source. Translated and adapted from Parra et al., 2022.

Stage. 1 - Problem definition

We used quantitative and qualitative data to understand the trends of the indicators during the modeling process. Qualitative data was collected through semi-structured interviews with expert informants and was processed through content analysis. This information enabled us to understand the economic housing production cycle in the MASLP and design the dynamic model. We selected the informants by chain or snowball sampling (Suprun et al., 2018).

We interviewed ten employees of social housing construction companies and ten urban policy experts (Table 1). The semi-structured interviews lasted an average of 50 minutes; to conduct them, we designed an instrument with questions on housing affordability, factors that increase the quantitative and qualitative housing deficit, subsidy policy, potential alternative housing policies, and significant challenges in the local social housing sector. A content analysis was carried out in Atlas Ti. The coding system was based on the model indicators. With the results, we created semantic networks, which were the basis for building the final structure of the model.

Table 1

Subjects interviewed

Subject	Position	Interview date	Subject	Position	Interview date
	Employees of construction companies and architectural practices			Urban policy experts	
# 1	Construction manager, Lara Architects	15/02/2023	# 11	Former director of public works, Municipality of San Luis Potosi	4/2/2023
# 2	Construction manager, M3G	21/02/2023	# 12	Director of cadaster and construction permits, Municipality of San Luis Potosi	18/02/2023
# 3	General director, LAMCO	5/3/2023	# 13	Director of public works, Municipality of San Luis Potosi	1/3/2023
# 4	Budget department manager, NOBLA	8/3/2023	# 14	Advisor, Municipal Planning Institute of San Luis Potosi	13/3/2023
# 5	General director, Guerrero Steel	15/3/2023	# 15	Advisor, Municipal Planning Institute of San Luis Potosi	26/3/2023
# 6	Director, Aguilar-Ruiz Architects	2/4/2023	# 16	Advisor, Municipal Planning Institute of San Luis Potosi	19/4/2023
# 7	Director, Sustaita Architects	15/04/2023	# 17	Budget department manager, CMIC, San Luis Potosi	24/04/2023
# 8	General director, COLBA	4/5/2023	# 18	Deputy associate, CMIC, San Luis Potosi	10/5/2023
# 9	General director, ALPA	11/5/2023	# 19	Deputy associate, CMIC, San Luis Potosi	19/5/2023
# 10	General director, PRESTOC	14/5/2023	# 20	MASLP real estate market analyst	4/6/2023

Source. Authors.

Historical series of socioeconomic and demographic data, subsidies granted, prices, costs, demand, and acquisition of social housing in the MASLP were obtained from institutional sources such as INEGI[4], INVIES, and CMIC[5]. The variables were selected based on secondary literature and expert interview data (Sprun et al., 2018). The MASLP was chosen for this case study because it is the area with the highest economic and

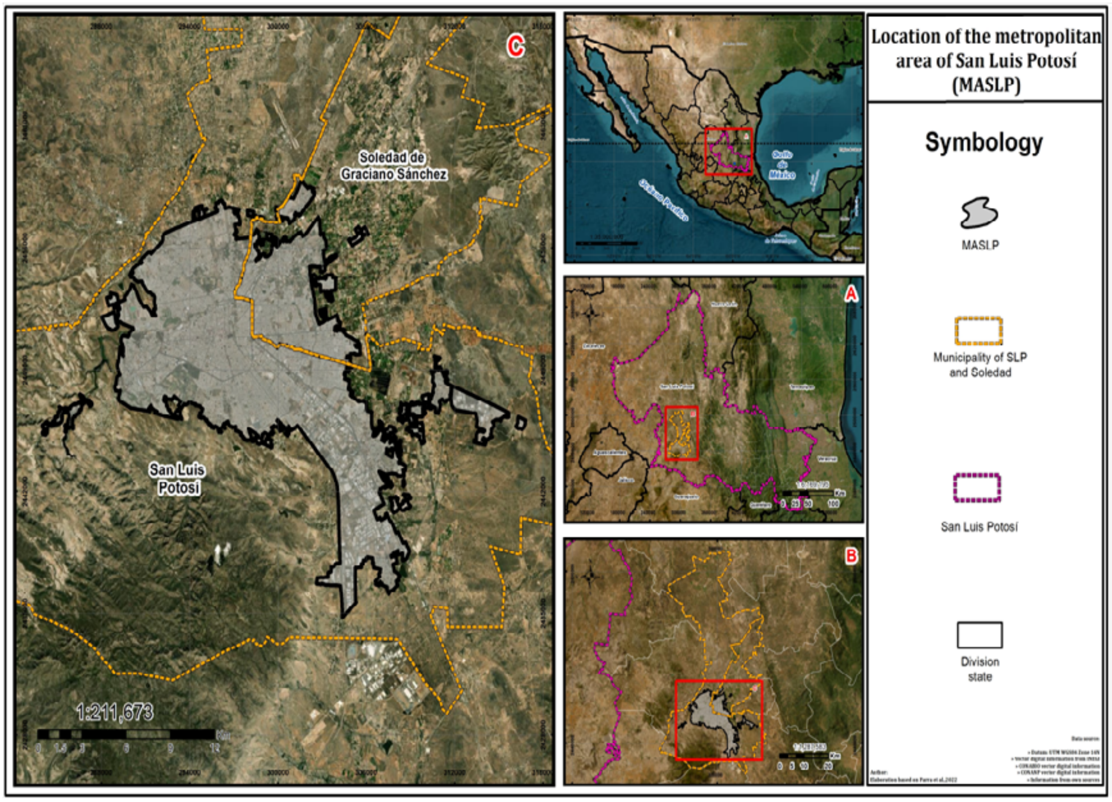
4. National Institute of Statistics and Geography (Instituto Mexicano de Estadística, Geografía e Informática).

5. Mexican Chamber of the Construction Industry (Cámara Mexicana de la Industria de la Construcción).

demographic growth and the greatest housing need in the state of San Luis Potosi, in addition to having one of the most expensive housing markets in the central region of the country (Figure 2).

Figure 2

Location of the Metropolitan Area of San Luis Potosí



Source. Based on Parra et al., 2022.

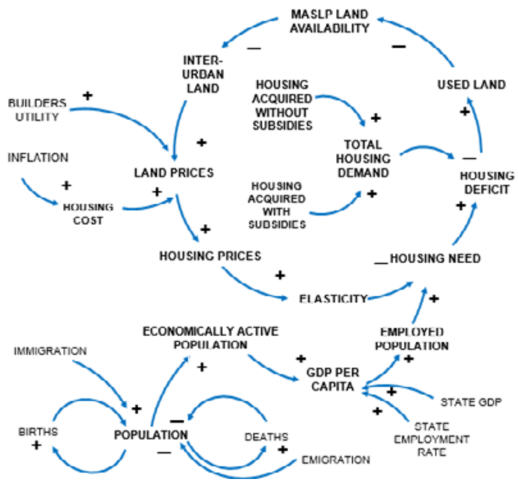
Stage. 2 – Conceptualization

The model's variable set and primary structure (Figure 3) were based on Parra et al. (2022). However, the polarity and flows of the interrelationships were validated with the information collected from the expert interviews. Housing need is an indicator that refers to the number of housing units necessary to meet families' needs annually. Housing demand refers to the total number of units acquired to cover this need. Population growth, the increase in GDP per capita, and the employed population directly affect housing needs (Dehgan et al., 2021; Kapourani & Kapmeier, 2017; Malmir & Spicar, 2015).

The employed population requires housing and acquires it under two modalities, with or without subsidies (Interviews 1,4,7). An increase in housing need reduces the housing deficit. The deficit increase reflects a market niche not being served (Interviews 8,4). As housing is built, more land is consumed (Barlas et al., 2007). Only 11.60 % of the MASLP area is interurban land, and as land availability decreases, its price increases (Interviews 12,14,20). Interviewees say developers' profits have narrow variation margins (between 8 and 10 %). As a result, land price increases do not affect their earnings as much as they impact housing prices (Interviews 2,3,5).

Figure 3

Causal diagram



Source. Translated and adapted from Parra et al., 2022.

Housing cost refers to the amount developers must cover to pay for the land and construction materials, labor, tools, and equipment to build one square meter of housing (Malmir & Spicar, 2015). In massive social housing developments, the housing cost per square meter also includes a proportional cost generated by the investment in land, urbanization, sewerage, water, and electrical networks (Interviews 18,20). The final sale price per square meter of housing includes utility and inflation (Interviews 2,8,10). Typically, a social housing plot measures 100 m^2 and the built footprint is 45 m^2 to 65 m^2. The price of the land refers to a plot of land that has water, drainage, and electrical infrastructure (Parra et al., 2022). Housing prices have a direct relationship with elasticity. This indicator refers to the effect of the increase in housing prices based on housing needs at an annual rate (Tandoh & Tewari, 2013). In Mexico, the elasticity effect on the social housing market is 0.63 (values under 1 are considered inelastic). However, the Sociedad Hipotecaria de Hacienda y Crédito Público (2018) estimates a significant effect in the coming years due to a constant increase in housing prices.

Stage. 3 – Dynamic model

We built the dynamic model using a causal diagram (Figure 3, Figure 4). This methodological tool enabled us to construct prospective scenarios for 2040. We classified the variables according to the specific function each has in the simulation (see Table 2). The symbols applied in the dynamic models built with Vensim PLE x64 represent processes. The loops represent the causal relationships between variables. Rectangles represent a process or level variables, and arrows represent flows; these connect level variables and indicate behavior and polarity change (refer to Appendix A). Vensim's table function was applied to represent projections and averages. Converters or parameters and constant values are represented by circles (Kapourani & Kapmeier, 2017).

After the model was built in Vensim Plex64, initial values, parameters, and constant values were entered. This crucial information allows trends and processes to be analyzed and informs decision-making. Population growth, GDP behavior, employed population[6], and economically active population directly affect demand and remain constant in all scenarios (trigger variables). Construction costs and housing acquired with subsidies are the variables we manipulated in constructing the three scenarios (refer to Appendix A). The housing deficit, total housing acquired, housing price, urbanized land, availability of land in the MASLP, housing acquired without subsidies, interurban land, and land prices are dependent variables.

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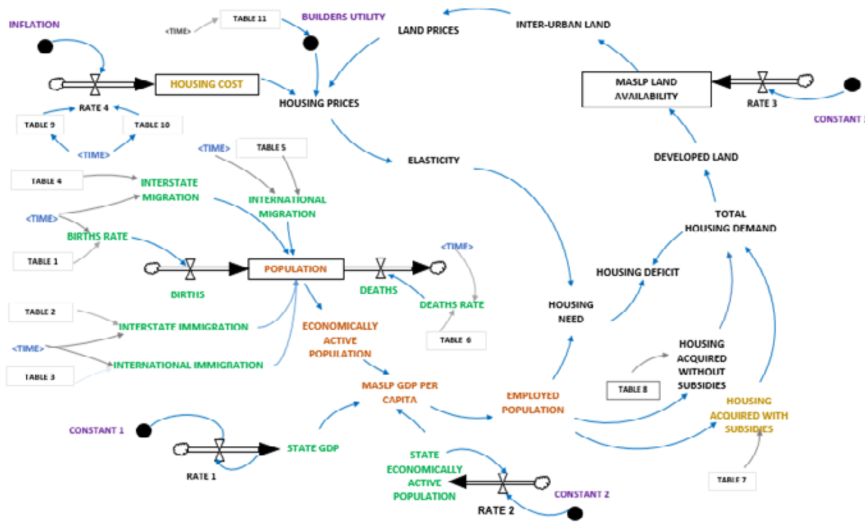
6. The economically active population is the sector that is old enough and able to be employed. The employed population is the sector that has employment income.

Figure 4

Dynamic model



Source. Translated and adapted from Parra et al., 2022.

Table 2

Dynamic model variables

Color	Variable Type
	Variables that trigger housing need
	Values applied to replicate the behavior of socioeconomic and demographic variables
	Constant values applied to replicate temporal patterns
	Shadow variables
	Dependent variables
	Independent variable
	Manipulated variables

Source. Authors

Temporal parameters for the construction of the scenario cover the 2010–2040 period. 2010 was used as the historical start date to project data (Gaytán-Hernández et al., 2017). This year was chosen based on data availability and uniformity with subsequent periods. The time step of the model is one year, and the integration method is Euler.[7] All these parameters were entered in Vensim to carry out the simulation (Appendix A shows the values and relationships of the dynamic model).

7. Function integrated into the Vensim algorithm to carry out simulations.

Stage. 4 – Model Analysis

We applied the behavior test method for scenario validation. This procedure evaluates whether the model's simulations resemble the behavior of the real system that is being modeled. It is crucial to obtain a high similarity between the projected data and the real system data since this corroborates the fact that the system behavior will be estimated realistically in the medium and long term (Kapourani & Kapmeier, 2017).

To validate the similarity of the results between the scenarios and the real-world data, we used linear correlation (R). This dimensionless statistical method describes the intensity of the relationship between two or more variables. Based on Gaytán-Hernández et al. (2017), the projections were considered valid when the observed and simulated data reached a degree of correlation (R) within the range [−0.4, −1] or [0.4, 1].

Figure 5 shows examples of the calibration process through the behavior test (Eskinasi, 2014; Gaytán-Hernández et al., 2018; Kapourani & Kapmeier, 2017). The MASLP population projections are based on data published by the National Population Commission (CONAPO). The correlation between the observed and simulated data is R = 0.910**, with a significance level of P > 0.001 (Figure 5. A). Based on Ibarra & Sotres (2008), the GDP per capita projection is based on the GDP at the state level. The correlation between the real and the simulated GDP data is R = 0.804* with a significance level of P > 0.001 (Figure 5. B).

The historical behavior of land availability in the MASLP was obtained from Alva and Martínez (2018). We interpolated data from this secondary source since primary sources that gather statistical and geographic information do not collect data on this variable. The correlation between the observed and simulated data is R = 0.994, with a significance level (P) > 0.001. The simulation and calibration of the price per square meter of social housing is based on information provided by local builders (Interviews 5,7,9) and the Camara Mexicana de la Industria de la Construccion (2020). historical database (2020). The correlation between the simulated and observed data was R = 0.998, with a significance level of (P) > 0.001.

Figure 5

Calibrations

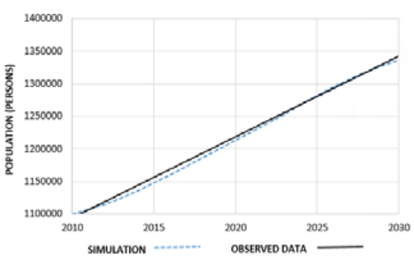


Fig. 5. A

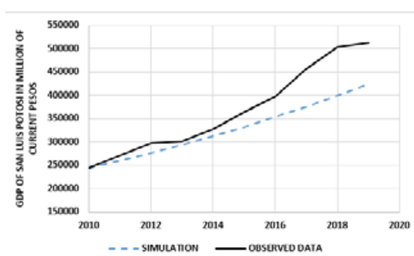


Fig. 5. B

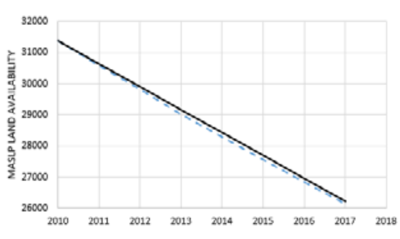


Fig. 5. C

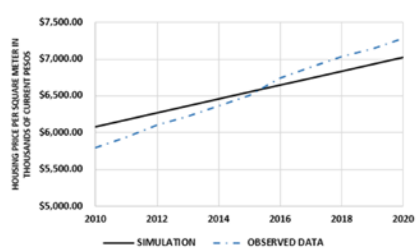


Fig. 5.D

Note. Calibration through the behavior test (A) Population growth. (B) GDP per capita. (C) Land availability. (D) Housing price. Source. Authors.

Stage. 5 – Scenarios

We simulated three scenarios that project the variables that trigger demand into the future (i.e., GDP, EAP, and employed population). We manipulated two variables, housing cost and housing acquired with subsidies, to estimate the future behavior of dependent variables (Figure 4). The first is a "trend" scenario that predicts what would happen if affordable housing costs per square meter continue increasing. At the same time, subsidies decrease, as observed in the last ten years' trend, and continue to cover less than 10 % of the housing deficit. Based on Malmir and Spicar (2015), the second "moderate" scenario explores the consequences of meeting 30 % of the social housing deficit and linearly increasing the housing cost to reach 10 % by 2040.

Finally, the third scenario, "Strong public investment," simulates an intervention that meets 70 % of the deficit in relation to the trend scenario. Land consumption sharply increases to achieve this deficit benchmark, and hence, so do housing costs. We designed this scenario to test these chain effects by increasing the housing cost by 32 % in relation to the first scenario from 2023 until 2040. In both scenarios, intervened variables' rates were selected after a series of iterations (For more details, see Appendix A).

Results

The information collected from the primary sources indicates that the governmental subsidy policies for housing acquisition are not effectively addressing the social housing deficit. According to Instituto de Vivienda de San Luis Potosi (INVIES) (2022), the number of subsidies delivered by the National Housing Commission in the MASLP has only met an annual average of 10 % of the housing demand in the last decade. Additionally, the shortage of affordable housing supply is significant because land prices in the MASLP are very high (Interviewees 13,16,19). This promotes investment migration to other locations, typically neighboring states with ejido land available (Interviewees 2,4). Investments also shift to other housing products, especially those with higher and quicker financial returns that target the population in higher income brackets (INVIES, 2022). The projection of the variables that trigger housing need (independent variables, Table 3) shows that if the current socio-demographic trend continues, population growth will be slightly over 100,000 people in twenty years (2020 to 2040). The GDP and the employed population also show an increasing trend.

Table 3
Independent variable projection in trend scenario

Year	Variables that trigger housing need		
	MASLP population	Employed population	GDP (MXN)
2020	1,180,296	47,2296	191,924
2030	1,269,363	50,4237	337,108
2040	1,280,931	55,2303	555,589

Source. Authors.

As a result, the need for housing also increased by 2,432 units in the same period, and the housing acquired without subsidy by 2,359 units (Table 4). The "trend" scenario projections show a clear and sustained housing deficit. They indicate that if the trend of the last ten years continues, by 2040 there will be a shortage of 4,464 social housing units.

Table 4

Projection of dependent and manipulated variables

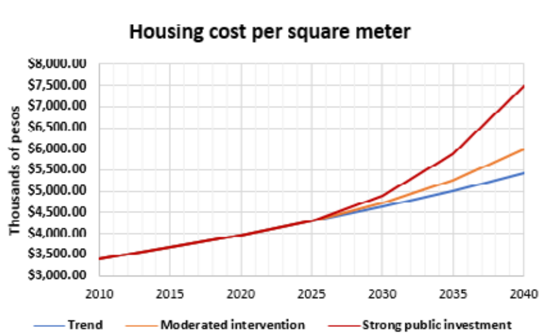
Scenarios		Dependent variables				Manipulated variables	
Number	Year	Housing deficit (units)	Housing price per m² ($ in MXN)	MASLP Interurban land (ha)	Land price per m² ($ in MXN)	Housing acquired with subsidies (units)	Housing cost per m² ($ in MXN)
First scenario (trend)	**2020**	4,320	7,025	2,795	2,735.00	1,357	3,972
	2030	4,446	8,011	2,101	3,000.00	1,264	4,640
	2040	4,463	9,704	1,523	3,219.00	1,287	5,421
Second scenario (moderate intervention)	**2020**	4,320	7,025	2,795	2,735.00	1,357	3,972
	2030	3,907	8,128	2,098	3,000.00	1,803	4,711
	2040	3,155	9,805	1,507	3,225.00	2,595	5,982
Third scenario (strong public intervention)	**2020**	4,320	7,025	2,795	2,735.00	1,357	3,972
	2030	3,181	8,313	2,094	3,000.00	2,530	4,881
	2040	1,222	11,487	1,485	3,234.00	4,529	7,503

Source. Authors.

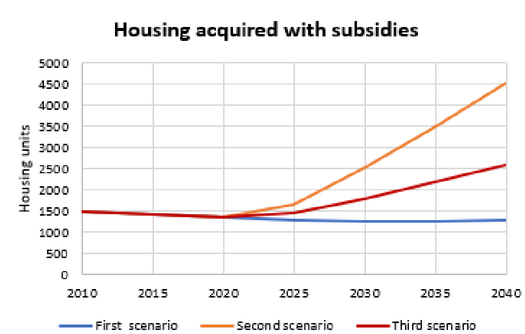
According to Scenarios 2 and 3, if social housing construction and subsidy provision increase to narrow the deficit gap by 30 and 70 %, respectively, the deficit drops to 2,595 units in the moderate intervention scenario and to 1,222 units in the strong intervention scenario (see Table 4).

Figure 6

Scenarios 'projections: Manipulated variables



6A



6B

Note. (A) Housing deficit projection. (B) Housing acquired with subsidies projection. *Source.* Authors.

However, the results also show that the price of available land will continue to increase based on supply and demand. This will be one of the main causal factors of social housing sale price increases (Table 4). The patterns indicate that if the trend continues, the cost per square meter of construction in the first scenario will be $MXN 5,422 by 2040 (6A). The simulated intervention through subsidies in the third scenario predicts an increase of $MXN 2,081 ($MXN 7,503 per m^2). In the second "moderate" scenario, the amount of subsidized housing is 2,596. With this increase in government support, the deficit would be 3,155 units, which represents a difference of 1,308 units with respect to the first scenario. In this case, the reduction in the gap is less than that observed in the third scenario; however, the increase in construction costs and prices is less pronounced.

Construction costs are reflected in the final housing prices, especially in social housing developments, given that profits derive from building massive amounts of units. If the cost of producing one unit increases, the cost of building a development is multiplied. According to projections, the housing prices per m^2 in 2040 will reach $MXN 9,075 in the trend scenario, $MXN 9,806 in the second scenario, and $MXN 11,479 in the third scenario (Table 4).

Projections also show that housing demand is inelastic. This means that rising housing prices do not discourage demand, given that housing is a basic commodity. The results show that if the trend continues, 2040 1,287 units will be acquired with a subsidy (Table 4), while 11,039 will be acquired through other financial mechanisms.

Discussion

The MASLP is in a region of sustained growth due mainly to industrial activity. This study analyzed the variables that trigger housing demand in this area (EAP, GDP, and employed population) and designed three scenarios where the number of houses acquired with subsidies and housing costs were manipulated to project housing need, demand, deficit, and cost, as well as land cost and price.

The dynamic model designed for this study uses a set of variables similar to those revised in the literature. However, other models' structures partialize the analyses by subdividing the variables into subloops that represent subsystems (territorial, social, political, economic) (Kapourani & Kapmeier, 2017; Zhang et al., 2018). This subdivision renders sub-systemic interaction between the relevant variables more difficult. Conversely, this study's model is based on a cyclical structure with a single main loop, which allows a comprehensive understanding of the interaction between the relevant variables.

Territorial systems are complex and exposed to the globalized environment's changes and variations. This is why prospective scenarios are not exact predictions of the future. However, their information is valuable for making decisions with a lower uncertainty factor in the strategic planning exercise. Therefore, although dynamic models do not replicate future reality, they do have the capacity to illustrate and understand the dynamics of the phenomenon, understand its nature, and have general guidelines for taking courses of action (Malmir & Spicar, 2015).

The analysis showed a steady increase in the variables that trigger housing needs. At the same time, housing demand shows a decreasing trend (trend scenario). This means the deficit gap increases over time, leaving many families without affordable housing options. The shortfall reflects a market gap that requires public policies to incentivize the offer and demand of affordable social housing and planning policies establishing territorial conditions to provide adequate housing.

Subsidies seek to fill the market gaps left by neoliberal social housing policies. The transformations of these policies in Latin America led governments to shift production responsibilities to private developers, if public investment needs to be reduced and that the market is more efficient. In the case of the first assumption, governments invest large amounts in subsidies and the public works needed to connect and serve peripheral developments (Hidalgo Dattwyler et al., 2022). The second assumption has shown that even if developers can build massive amounts of social housing in short periods (thus attending a need), location and quality are undermined and trigger social problems and housing abandonment. In the MASLP, social housing development is driven by the market. Hence, according to informants, the production process is controlled by a few large developers who secured land reserves, inserted their interests into the city's planning, and built large social housing developments in poorly served areas (Interviewees 9,12,15).

Even if recent subsidy programs such as *Hipoteca Verde* seek to promote the construction of well-served, centrally located developments, studies show that they are ineffective in containing urban expansion and promoting development near massive transportation and services (Ferniza, 2021). Furthermore, subsidies seek to increase affordability and bust housing acquisition by the poorest sectors of the population (Blanco, 2010; Ho et al., 2012; Malmir & Spicar, 2015). However, the projections show that social housing values will continue to increase and be unaffordable for many. For those households still able to afford a house, debt increases, and only one out of every thirteen families will have access to a subsidy to cover a mortgage down payment. Despite this, projection results show, in line with Malmir and Spicar (2015), that significantly increasing the number of subsidies to fuel demand can have an adverse effect by negatively impacting housing prices. Increasing the number of subsidies in the MASLP to reduce the deficit by 70 % (Scenario 3) increases the final housing price by 16 % compared with the trend scenario.

Well-served interurban land in the MASLP is scarce and expensive. However, developing social housing in the periphery where land is cheaper promotes housing abandonment and poor quality of life (Rodríguez y Sugranyes, 2011). As a result, increasing social housing construction to reduce the deficit consumes land and contributes to increasing its value. Also, according to interview findings, when construction activity rallies, costs increase due to workforce scarcity and appreciation of material costs. With developers' narrow profit margins, the main impacts of cost increases are absorbed by the captive consumers of an inelastic good.

The projections exhibit a stable deficit and a sustained increase in housing prices that two decades of subsidy policies have not been able to tame (INVIES, 2022). The MASLP case shows similarities to the Uruguayan context, which, under a banner that seeks to benefit the poorest sectors, serves the purposes of the construction and financial institutions that use them to reduce investment risks (Magri, 2013). If housing prices continue to rise steadily, as shown by projections, affordability will be further compromised, and the effect of subsidies on housing acquisition will be null. According to Blanco (2010), these conditions, coupled with inefficient alternative financing sources and a lack of suitable land for housing development, drove the expansion of informal developments in Bogota, Colombia. A similar situation has also been documented in the metropolitan areas of Argentina, Brazil, Chile, and Mexico, where real estate price hyperinflation is correlated with urban growth in poorly served and at-risk informal settlements (Cardo, 2016; Hidalgo Dattwyler et al., 2021; Olivera, 2018).

Promoting sustainable urban growth and suitable affordable housing must be addressed by comprehensive urban policies. The marginal contribution of subsidy programs can be rectified if the housing deficit gap is closed by 30 % through public subsidy (Scenario 2). This tipping point avoids the significant impact on housing prices that results from Scenario 3 and promotes a housing demand increase. However, the causal effects of increasing the number of subsidies provided (i.e., the rise in construction and land costs) need to be addressed simultaneously to avoid further promoting housing unaffordability.

In addition to subsidies, urban planning policies must be implemented in parallel to reduce price hyperinflation and activate social housing acquisition with mechanisms such as publicly-owned land reserves, tax incentives for developers, and credits with low interest rates, such as the policies projected by Ho et al. (2015) for Taichung City.

In Santiago de Chile and Johannesburg, South Africa, subsidy policies were complemented with urban and administrative strategies such as a cautious release of interurban land reserves to indirectly control and regulate land price hyperinflation caused by construction rate increases and administration fee exemptions for developers that invest in poor areas (Gilbert, 2004; Programa de las Naciones Unidas para los Asentamientos Humanos [UN-Habitat], 2020). To implement these mechanisms, legal and public administration improvements (e.g., efficiency, transparency) need to be implemented to avoid what participants referred to as corrupt processes that do not contribute to reducing the housing deficit in Latin America (Bautista, 2012; Hauk et al., 2022).

Conclusions

This paper analyzed the behavior of subsidy policies in the Metropolitan Area of San Luis Potosi (MASLP). The study designed a dynamic model with a cyclical structure to understand the relationships between subsidies, population, land availability and housing construction, prices, and acquisition. The model projected these and other variables into the future (2040) based on three scenarios: a trend scenario and moderate and robust public intervention. The latter two envision a subsidy increase to reduce housing demand by 30% and 70 %, respectively.

Dynamic modeling proved to be a valuable tool for informing policy and forecasting the behavior of variables. However, the study faced limitations related to data availability[8]. These limitations were nonetheless addressed with information from peer-reviewed secondary sources. Modeling the behavior of a complex system may also be complicated by methodological limitations and may thus yield results that are not consistent with reality. This paper addressed these limitations through variable calibration with high significance levels and scenario validation using correlation and regression to assemble a reliable database.

8. For example, INEGI does not report the GDP per capita at the municipal level. Therefore, this value was estimated based on Parra et al. (2022). Other geographical data such as the annual consumption rate of interurban land is not provided by official sources. As a result, it was calculated based on secondary sources (Alva y Martínez, 2018).

These quantitative techniques were complemented in this study by the expert perceptions of carefully selected key informants to define the variable set and model structure.

These methods show that if the current trend continues, housing acquired with subsidies will steadily decrease while the housing deficit remains the same, and housing prices will rise. Increasing subsidies by 30 % proved to be the best-case scenario to significantly reduce the housing deficit and increase purchases despite a housing price increase.

These results provide public policy tools for decision-makers seeking to increase housing demand through public funds invested in subsidies. The analyses show a threshold above which subsidy provision may yield adverse results by highly impacting housing prices. Even when social housing demand is inelastic, its affordability is threatened by rising land values, construction, and workforce costs. This mainly impacts households in the lowest income brackets.

Policy changes in the MASLP are needed in the next five years to promote the affordability of social housing and control the driving forces that stimulate the increase in land and housing prices. However, subsidies alone will not foster these changes; these programs need to be coupled with alternative policies and urban strategies that target quantitative goals and address people's quality of life. Some authors recommend promoting other housing alternatives, such as the rental housing market, by reinforcing the legal framework to increase the legal certainty of owners and tenants (López, 2010), including other actors in policy implementation through public-private partnerships to enhance the capacity of subsidies, and monitoring the implementation of policy to secure adequate housing sizes and locations (Salazar et al., 2015); and promoting more active public intervention to improve affordability and acquisition rate by reducing income tax rates, down payments, and interest rates, increasing subsidy amounts and eliminating or drastically reducing the property transfer tax on housing sales (López, 2010).

Nonetheless, while these recommendations address some of the externalities caused by housing financing, Hidalgo Dattwyler et al. (2022) argue that they overlook capital's predatory dynamics and their consequences for the most disadvantaged. These policies do not seek to change the basic mechanisms of the dynamics of capital but to address its consequences; therefore, future research could explore alternatives that support the collective production of housing, as well as the use of subsidy policies that align with planning strategies to encourage the production of mixed and accessible housing.

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Conflicto de interés

Los autores no tienen conflictos de interés que declarar.

Declaración de autoría

Lourdes Marcela López-Mares: Conceptualización, Investigación, Administración del proyecto, Redacción – borrador original, Redacción – revisión y edición.

Omar Parra-Rodríguez: Análisis formal, Investigación, Metodología, Validación, Redacción – borrador original.

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Appendix A

The equation table is based on Parra et al. (2022). In that case, the operated variables focused on land availability. However, for this model, the variables manipulated for scenario construction are housing price, housing cost, and subsidy amount. These differences justify the inclusion of the table. Furthermore, presenting the model equations explicitly allows the results to be fully replicated.

EQUATIONS AND COMMENTS
(1) POPULATION= ((BIRTHS-DEATHS) +(INTERSTATE MIGRATION-INTERSTATE IMMIGRATION) -(INTERNATIONAL MIGRATION-INTERNATIONAL IMMIGRATION)) +STEP (1500, 2012) +STEP (1500, 2014) +STEP (1500, 2016) + STEP (1500, 2018) + STEP (1500, 2020) +STEP (1500, 2022) + STEP (1500, 2023)-STEP (900, 2025)-STEP (1200, 2027)-STEP (1300, 2029)-STEP (1000, 2032) **INITIAL VALUE**= 1.1e+06 We used a variable level, the STEP function of Vensim, and the National Population Commission projections to simulate population growth. **Source:** (Consejo Nacional de Poblacion, 2020).
(2) BIRTHS= BIRTH RATE * 1000
(3) BIRTH RATE= (TABLE 1 BIRTH*TIME) **TABLE 1**= [(2010,12)(2040,30)], (2010,20.5), (2015,18.75), (2020,17.18), (2025,15.83), (2030,14.49), (2035,13.39), (2040,12.49) **Source:** (Consejo Nacional de Poblacion, 2020).
(4) INTERSTATE IMMIGRATION = (TABLE 2 IMMIGRATION INTEREST*TIME) **TABLE 2**= [(2010,0)(2040,20000)], (2010,17196), (2015,11064), (2020,10744), (2025,10267), (2030,9740), (2035,9168), (2040,8580) **Source:** (Consejo Nacional de Poblacion, 2020).
(5) INTERNATIONAL IMMIGRATION = (TABLE 3 MIGRATION INTER*TIME) **TABLE 3**= [(2000,3000)- (2050,4000)], (2010,3320), (2015,3204), (2020,3276), (2025,3380), (2030,3446), (2035,3504), (2040,3522) **Source :** (Consejo Nacional de Poblacion, 2020).
(6) INTERSTATE MIGRATION = (TABLE 4 INTERSTATE MIGRATION*TIME) **TABLE 4**= [(2010,0)(2040,20000)], (2010,16000), (2015,14667), (2020,13617), (2025,12236), (2030,10884), (2035,9617), (2040,8473) **Source :** (Consejo Nacional de Poblacion, 2020).
(7) INTERNATIONAL MIGRATION = (TABLE 5 MIGRATION INTER*TIME) **TABLE 5**= [(0,0) -(3000,20000)], (2010,8834), (2015,9731), (2020,10480), (2025,11175), (2030,11525), (2035,11734), (2040,11835) *Source*. (Consejo Nacional de Población, 2020).

(8) DEATHS= MORTALITY RATE*1000

(9) MORTALITY RATE= (TABLE 6 MORTALITY*TIME)
TABLE 6= [(2010,6) -(2040,8.5)], (2010,6.2), (2015,6.27), (2020,6.71), (2025,6.92), (2030,7.18), (2035,7.56), (2040,8.02)

This is the proportion of deaths with respect to the number of individuals that inhabit a population, country, city, state; in one year.
Source : (Consejo Nacional de Poblacion, 2020).

(10) ECONOMICALLY ACTIVE POPULATION= POPULATION*0.4384

According to the historical series of the INEGI, the economically active population (population between 20-64 years) of the MASLP represents 43.84% of the total population (Instituto Nacional de Estadistica y Geografia, 2024).

(11) MASLP GDP PER CAPITA= ((ECONOMICALLY ACTIVE POPULATION *0.9438/ STATE ECONOMICALLY ACTIVE POPULATION) *STATE GDP)

The MASLP integrates several municipalities, and the GDP per capita is data not collected at the municipal level. Therefore, the number of the economically active and employed population in the MASLP was taken, and its percentage of inference in the employed population at the state level was calculated. We multiplied the result by the state GDP (Instituto Nacional de Estadistica y Geografia, 2024).

(12) STATE GDP= GDP RATE
INITIAL VALUE= 244786

We used a level variable to simulate the GDP a state level. INEGI provided the historical series regarding the behavior of the Gross Domestic Product of San Luis Potosí (Instituto Nacional de Estadistica y Geografia, 2024).

CONSTANT 1= 0.063

RATE 1= CONSTANT * ESTATE GDP

(13) STATE ECONOMICALLY ACTIVE POPULATION = STATE ECONOMICALLY ACTIVE POPULATION RATE
INITIAL VALUE= 1.01729e+06

We used a level variable to simulate the economically active population (Instituto Nacional de Estadistica y Geografia, 2024).

CONST 2= 0.0121124

RATE 2= STATE ECONOMICALLY ACTIVE POPULATION * CONST 2

(14) EMPLOYED POPULATION = 0.22* MASLP GDP PER CAPITA +430073

To simulate and project the behavior of the economically active population, we built a linear regression function based on data from the Instituto Nacional de Estadistica y Geografia (2024).

(15) HOUSING NEED= EMPLOYED POPULATION*0.0304+ELASTICITY

To simulate and project the behavior of housing demand, we built a linear regression function taking as a calibration base the data reported in the Comision Nacional de Vivienda (2024).

(16) ELASTICITY = IF THEN ELSE (HOUSING PRICE<=8100,0, HOUSING PRICE*-0.004)

Currently the social housing market in Mexico is inelastic. However, the variable is included, since Parra et al. (2022) affirms that price inflation will have an effect on demand in the medium term. To simulate this prediction, and to represent the beginning of an elastic effect, a limit on the price per m^2 of $8,100 was proposed. Thereafter, each 1% increase in the price of housing would correspond to a 3% decrease in demand annually. This is a parameter proposed by experts in the local real estate market. Source: (Sociedad Hipotecaria de Hacienda y Credito Publico, 2018).

(17) HOUSING DEFICIT= HOUSING DEMAND- HOUSING ACQUIRED

The housing deficit is the difference between the housing demanded minus the housing acquired.

(18) HOUSING DEMAND = HOUSING ACQUIRED WITH SUBSIDIES + HOUSING ACQUIRED WITHOUT SUBSIDIES

(19) HOUSING WHIT SUBSIDIES= TABLE 7 (Time)* EMPLOYED POPULATION

TABLE 7 SCENARIO 1 = (2050,0.004)], (2010,0.0032957), (2011,0.00326056), (2012,0.00322476),(2013,0.0031841), (2014,0.00314301),(2016, 0.0030 305181),(2017,0.00300708),(2018,0.002963),(2019,0.00291783),(2020,0.00287524),(2021,0.0028316),(2022,0.0027922),(2023,0.0027497),(2024,0.00270616),(2025,0.00266481),(2026,0.00262923),(2027,0.00259361),(2028,0.0025639),(2029,0.00253391),(2030,0.00250784),(2031,0.0024849),(2032,0.00246132),(2033,0.00244246),(2034,0.00242284),(2035,0.00240598),(2036,0.00239006),(2037,0.00237322),(2038,0.00235893),(2039,0.00234365),(2040,0.00233087)

TABLE 7 SCENARIO 2 = [(2010,0.002) -(2040,0.009)], (2010,0.0032957), (2011,0.00326056), (2012,0.00322476), (2013,0.0031841), (2014,0.00314301), (2015,0.00309749), (2016,0.00305181), (2017,0.00300708), (2018,0.002963), (2019,0.00291783), (2020,0.00287524), (2021,0.0028316), (2022,0.0027922), (2023,0.00279), (2040,0.0047)

TABLE 7 SCENARIO 3 = [(2010,0.002) -(2040,0.009)], (2010,0.0032957), (2011,0.00326056), (2012,0.00322476), (2013,0.0031841), (2014,0.00314301), (2015,0.00309749), (2016,0.00305181), (2017,0.00300708), (2018,0.002963), (2019,0.00291783), (2020,0.00287524), (2021,0.0028316), (2022,0.0027922), (2023,0.00279), (2040,0.0082)

The values in the table will depend on the scenario being built. Source: (Comision Nacional de Vivienda, 2024).

(20) HOUSING WITHOUT SUBSIDY = TABLE 8 (Time)* EMPLOYED POPULATION

TABLE 8 = [(2005,0.0176) (2050,0.0201)], (2010,0.0179431), (2011,0.0179755), (2012,0.0180098), (2013,0.0180469), (2014,0.0180861), (2015,0.0181284),(2016,0.0181732),(2017,0.0182208),(2018,0.0182702),(2019,0.0183227),(2020,0.0183773),(2021,0.0184351),(2022,0.0184952),(2023,0.0185589),(2024,0.0186263),(2025,0.0186962),(2026,0.0187679),(2027,0.0188421),(2028,0.0189176),(2029,0.0189956),(2030,0.0190747),(2031,0.0191562),(2032,0.0192402),(2033,0.0193253),(2034,0.0194129),(2035,0.0195028),(2036,0.019595),(2037,0.0196896),(2038,0.0197865),(2039,0.0198857),(2040,0.0199871)
Source: (Comision Nacional de Vivienda, 2024).

(21) HOUSING DEMAND = HOUSING WITHOUT SUBSIDY + HOUSING WHIT SUBSIDIES

(22) DEVELOPED LAND= (HOUSING DEMAND *100) *1.45/10000

The lots for social housing in the ZMSLP have an average area of 100 m^2 (Parra et al., 2022). The number of homes purchased was multiplied by the area of the lots, with an additional percentage of 43% for roads, green areas and donation areas. These amounts come from the regulations for the construction of housing developments in the state of San Luis Potosí. As a next step, we divide the value by 10,000 to obtain the final value in hectares.

(23) AVAILABLE LAND IN MASLP = RATE 3 - DEVELOPED LAND
INITIAL VALUE= 31388

To simulate the available land in MASLP we used a variable level. The institutes that collect statistical and geographic information do not collect available interurban land percentages. Therefore, we used the projection previously made by Alva & Martínez (2018) to simulate the hectares consumed by the urban growth of the MASLP.

CONSTANT 3 = -0.021

RATE 3= AVAILABLE LAND * CONSTANT 3

(24) INTERURBAN LAND

San Luis Potosí Municipal Development Plan indicates that housing projects only can be built on interurban land. Only 11.60% of the MASLP is interurban land. This percentage and the data from Alva & Martínez (2018) were the criteria for building the indicator.

(25) LAND PRICES= -0.381* INTERURBAN LAND +3800

The Camara Mexicana de la Industria de la Construccion (2020) provided the historical series of land prices in San Luis Potosí. We applied a bivariate linear regression between the availability and price of interurban land, placing the latter as the dependent variable. The results show an R = -0.970. This indicates that the decrease in the availability of land corresponds to an increase in the price. The equation of the regression line (y = mx + b) allowed to establish the value of the constant and the slope.

(26) HOUSING COST =
SCENARIO 1 **HOUSING COST** = HOUSING COST * RATE 4 * INFLATION + (TABLE 9*Time (0)) +(TABLE 10*Time (0))
INITIAL VALUE= $3,400
RATE 4= 0.015

SCENARIO 2 **HOUSING COST** = HOUSING COST * RATE 4 * INFLATION* INFLATION+ (TABLE 9*Time) +(TABLE 10*Time (0))
RATE 4= TABLE 9 * Time
TABLE 9 = [(2010,0.01) -(2040,0.04)], (2010,0.015), (2015,0.015), (2020,0.015), (2021,0.015), (2022,0.015), (2023,0.015), (2040,0.027)

SCENARIO 3 **HOUSING COST** = HOUSING COST * RATE 4 * INFLATION* INFLATION+ (TABLE 9*Time (0)) +(TABLE 10*Time)
RATE 4= TABLE 10 * Time

TABLE 10 = [(2010,0.01) -(2040,0.04)], (2010,0.015), (2015,0.015), (2020,0.015), (2021,0.015), (2022,0.015), (2023,0.015), (2040,0.055)

For the scenario's construction, we make a variation in the values of housing cost in each case. We used a variable level for this indicator. The projections were validated by the experts interviewed. Also, the Camara Mexicana de la Industria de la Construccion (2020) provided the parametric costs per m^2 of social housing construction. This is the cost per m^2 in the year 2010. The cost includes the annual inflation rate.

(27) INFLATION= 1.045

(28) UTILITY=

SCENARIO 1 UTILITY = Table 11*Time
Table 11= [(2010,1) -(2040,2)], (2010,1.08), (2015,1.08), (2020,1.08), (2021,1.08), (2022,1.08), (2023,1.08), (2040,1.08)

SCENARIO 2 UTILITY = Table 11*Time
Table 11= [(2010,1) -(2040,2)], (2010,1.08), (2015,1.08), (2020,1.08), (2021,1.08), (2022,1.08), (2023,1.08), (2040,1.1)

SCENARIO 3 UTILITY= Table 11*Time
Table 11 = [(2010,1) -(2040,2)], (2010,1.08), (2015,1.08), (2020,1.08), (2021,1.08), (2022,1.08), (2023,1.08), (2040,1.1)

The MASLP social housing builders state that current market trends only allow a profit of between 8 and 10% in this type of project. Therefore, the utility in the 3 scenarios remained within these parameters. However, for the construction of the scenarios there is a variation in utility.