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Original Article

System dynamics for exploring commercial expansion scenarios in a hardware distribution company

Dinámica de sistemas para explorar escenarios de expansión comercial en una empresa ferretera

Diego León Peña Orozco[1] Mauricio López Orozco[1] Andrés Mauricio Paredes Rodríguez[2] Jesús González-Feliu[3]

[1]Industrial Engineering Program, Unidad Central del Valle del Cauca, Tuluá, Colombia.
[2]Industrial Engineering Program, Universidad del Valle, Cali, Colombia.
[3]Scientific Coordinator for public funded calls for projects at Excelia Business School, La Rochelle, France.

Abstract

Introduction: Long-term commercial expansion through independent commercial partners involves feedback among candidate identification, partner activation, withdrawal and demand generated through multiple channels. This study examines those relationships in an anonymized medium-sized Colombian distributor of hardware and construction products using system dynamics.
Objective: To develop a case-based system dynamics model that supports managerial discussion, explores the behavior of a proposed commercial-partner network under alternative assumptions, and demonstrates how acquisition, withdrawal, capacity, sales transition and channel demand interact over time.
Methodology: A deterministic stock-and-flow model was implemented in Vensim PLE 10.4.0 using monthly historical averages derived from the company's Enterprise ERP system for 2017-2019 and case-specific business assumptions. Monthly demand (units/month) was separated from cumulative demand (units). Simulations used Euler integration over 240 months with a one-month time step.
Results: The dimensional-consistency assessment produced no unit errors, and the model generated the expected behavior in the five documented extreme-condition tests. Relative to the 18% baseline, the 25% and 35% acquisition scenarios increased monthly demand at month 48 by 2.83% and 5.07% respectively. At month 240, the increases were 2.16% and 3.88% and cumulative demand was 2.54% and 4.54% higher.
Conclusions: The model is internally consistent and contextually plausible for exploratory analysis and methodological demonstration under explicit assumptions. Its outputs may support managerial discussion and provide preliminary inputs for subsequent capacity, inventory and logistics studies, but those decisions are not optimized in this research.

Keywords: Commercial expansion, System dynamics, Exploratory simulation, Demand trajectories, Hardware company.

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Correspondence

mlopezo@uceva.edu.co

Spanish version

Resumen

Introducción: La expansión comercial de largo plazo mediante aliados comerciales independientes involucra realimentaciones entre la identificación de candidatos, la activación y el retiro y la demanda generada por distintos canales.
Objetivo: Desarrollar un modelo de dinámica de sistemas basado en un caso empresarial que apoye la discusión gerencial, permita explorar el comportamiento de una red propuesta de aliados comerciales y demuestre la interacción entre adquisición, retiro, capacidad, transición de ventas y demanda por canal.
Metodología: Se implementó en Vensim PLE 10.4.0 un modelo determinista de niveles y flujos, empleando promedios históricos mensuales obtenidos del ERP Enterprise para 2017-2019 y supuestos empresariales específicos del caso. Se separó la demanda mensual (unidades/mes) de la demanda acumulada (unidades). Las simulaciones utilizaron integración Euler durante 240 meses, con un paso mensual.
Resultados: La evaluación de consistencia dimensional no identificó errores de unidades y el modelo generó el comportamiento esperado en las cinco pruebas de condiciones extremas documentadas. Frente al escenario base del 18%, las tasas de adquisición de 25% y 35% incrementaron la demanda mensual en el mes 48 en 2,83% y 5,07% respectivamente. En el mes 240, los incrementos fueron 2,16% y 3,88%, mientras que la demanda acumulada aumentó 2,54% y 4,54%.
Conclusiones: El modelo es internamente consistente y contextualmente plausible para la exploración y demostración metodológica bajo supuestos explícitos. Sus resultados permiten interpretar trayectorias condicionales para apoyar la discusión gerencial y análisis posteriores.

Palabras clave: Expansión comercial, Dinámica de sistemas, Simulación exploratoria, Trayectorias de demanda, Distribución ferretera.cos

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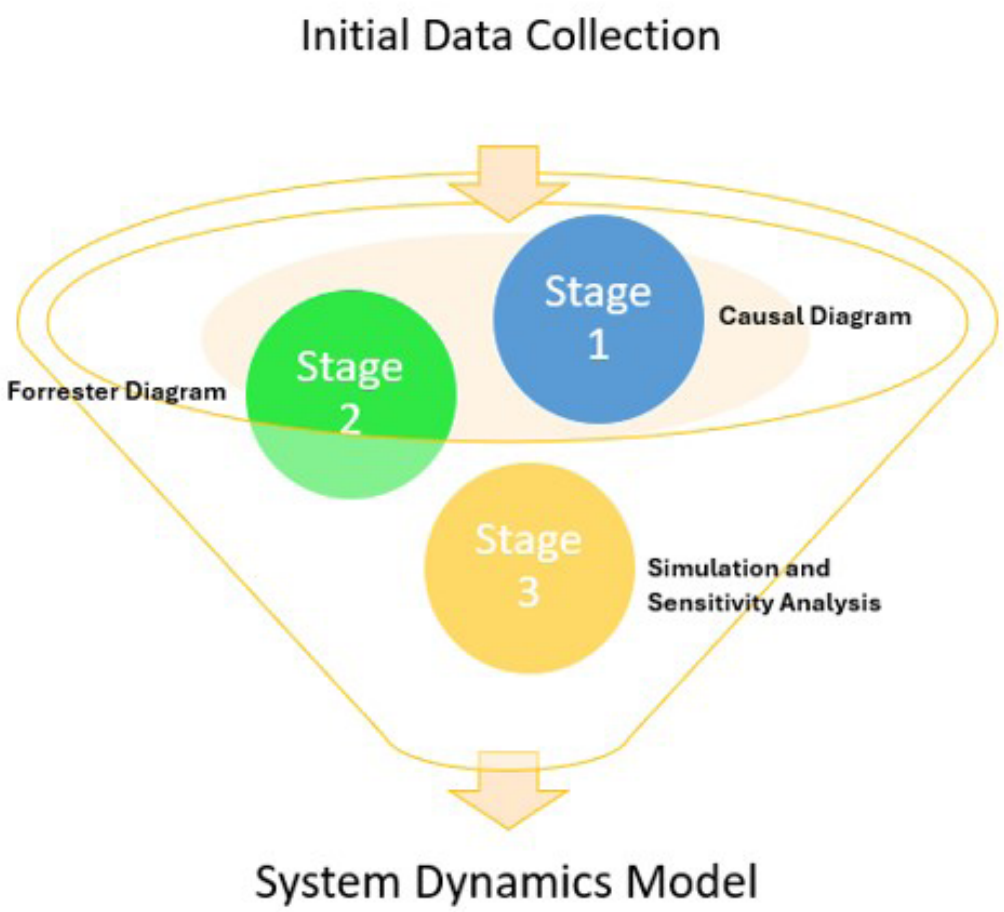
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Why was this study conducted?
This study contributes an applied, case-based system dynamics representation of expansion through independent commercial partners. It links candidate generation, partner activation, capacity, withdrawal and retail, wholesale, online and partner-related demand. Its methodological contribution lies in making the assumptions and stock-and-flow logic transparent, separating monthly demand from cumulative demand and documenting structural, dimensional, extreme-condition, and deterministic sensitivity tests. The contribution is exploratory and demonstrative rather than predictive.

The most relevant results include:
The deterministic sensitivity experiment shows ordered but attenuating responses to higher acquisition assumptions. Increasing acquisition from 18% to 25% and 35% increases cumulative demand at month 240 by 2.54% and 4.54%, respectively, while the relative monthly-demand effect decreases after the acquisition window closes.

These results contribute to the following:
The simulation trajectories can serve as preliminary demand inputs for subsequent studies of capacity, inventory, distribution-center design and transport resources. The present model does not directly evaluate or optimize those decisions.

Graphical Abstract



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Introduction

Small and medium-sized enterprises are important contributors to employment and economic activity, yet they face persistent pressure from globalization, technological change and shifts in customer behavior (1,2). Partner-based commercial expansion therefore requires explicit representations of how candidate businesses enter, remain in, and leave a network and how those changes affect demand over time. Previous research has linked organizational strategy with performance measurement and supply-chain configuration (3-5), while studies of business-model innovation have emphasized the role of dynamic capabilities in responding to changing environments (6,7). Industry 4.0 technologies and data analytics may support such strategies, but their value depends on the organization´s ability to connect data, causal assumptions and managerial decisions (8,9).

The case organization is an anonymized medium-sized Colombian company engaged in the wholesale and retail commercialization and distribution of hardware, construction materials and related products. During the 2017-2019 reference period, it operated three branches in intermediate cities in Valle del Cauca and served markets in Valle del Cauca and northern Cauca. Its proposed fractal strategy sought to expand through independent wholesale customers or commercial establishments operating under collaborative commercial arrangements. Prospective expansion discussions considered other territories in western Colombia, including the Coffee Region and Antioquia. Company identity, branch locations and commercially sensitive information are withheld. System dynamics is appropriate for examining feedback, delays, accumulation, capacity constraints and nonlinear behavior in complex organizational systems (10-13). In this case, the approach represents the interaction between the potential-partner pool, active partners, withdrawal, channel demand and sales transition. Supply chain integration provides a substantive setting for this representation because coordination among independent firms may influence responsiveness and operating performance (14-16). Statistical forecasting and event-based simulation frameworks serve analytical purposes different from those of stock-and-flow modeling (17,18). The model was developed to support multidisciplinary managerial discussion of the proposed expansion, explore system behavior under alternative assumptions and demonstrate the usefulness of system dynamics for representing the decision problem. The simulated trajectories are conditional consequences of the structure and assumptions rather than point predictions. The formal partner-acquisition period was set at 48 months, consistent with the implementation horizon of the company's four-year innovation project. The simulation was extended to 240 months as a technical modeling decision to observe whether partner stocks and demand trajectories converged, stabilized or declined after acquisition ceased. The 20-year horizon is an analytical window used to examine long-run endogenous behavior after partner acquisition ceases; it is not a corporate plan or a sales forecast.

Accordingly, this study develops a case-based system dynamics model to support managerial discussion, explore how partner acquisition, withdrawal, capacity, sales transition and channel demand shape conditional long-term trajectories, and demonstrate the application of stocks-and-flow modeling to a partner-based commercial expansion strategy. It also documents the equations, dimensional structure, extreme-condition tests, and quantitative sensitivity to the acquisition assumption.

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Materials and Methods

The methodological framing draws on the dynamic-strategy perspective, which understands competitive positioning and organizational performance as processes that evolve over time rather than as static conditions (19). Within this perspective, system dynamics represent feedback relationships, accumulations, delays, and the consequences of managerial assumptions in complex organizational systems (10,13). Previous studies have demonstrated its usefulness for examining value-creation mechanisms and information effects in managerial settings (20), as well as the long-term interaction between organizational capabilities and capability erosion (21). In the present study, these foundations support an exploratory and case-based representation of the proposed commercial-expansion mechanism; they are not used to claim predictive forecasting accuracy.

The study followed a single-case modeling design. Its sequence comprised system characterization, construction of the causal representation, conversion into a stock-and-flow model, model checking, deterministic simulation and sensitivity analysis. Model relationships and case assumptions were reviewed iteratively through multidisciplinary technical discussions involving general management, logistics, point-of-sale and wholesale commercial leadership, information systems, purchasing and management-systems and quality personnel. Differences were addressed through technical discussion and consensus, followed by management acceptance. This process supports the contextual and structural plausibility of the model.

The modeling procedure comprised three stages, as shown in Figure 1. First, a causal diagram was developed to represent the relationship among the variables associated with the proposed commercial-partner network and channel demand. Second, the causal structure was translated into a stock-and-flow model containing level, flow and auxiliary variables. Third, the model was parameterized using aggregated monthly information obtained from the company's Enterprise ERP system from 2017-2019 and case-specific assumptions established through the multidisciplinary review process. The deterministic model was then subjected to dimensional-consistency assessment, extreme-condition testing, baseline simulation and sensitivity analysis. The numerical application represents retail, conventional wholesale, online and active-partner demand at the aggregation level supported by the available information. Although the company managed approximately 14,000 SKUs organized into 14 commercial lines, the original disaggregated dataset and calculation sheets were unavailable. Consequently, the study does not claim that separate simulations were executed for every product subline or that the numerical results represent the company's complete portfolio.

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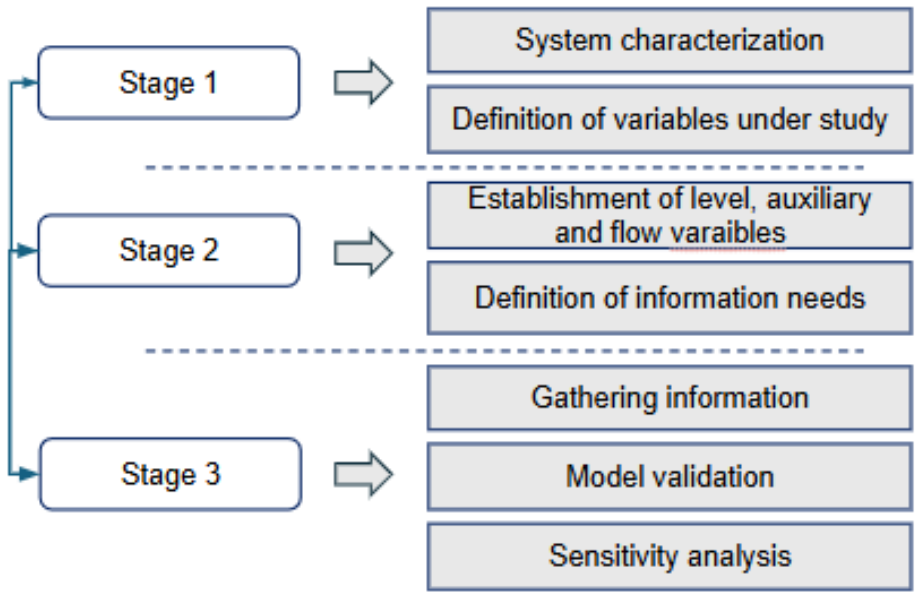


Figure 1. Procedure used to construct, check and analyze the system dynamics model.

Model boundary and causal structure

The model boundary includes prospective partners, active partners, partner activation, active-partner withdrawal, growth and loss of prospective partners, organizational capacity, retail demand, wholesale demand, online demand, sales transition, demand per active partner, monthly demand and cumulative demand. Macroeconomic variables, inflation, technological regime shifts, pandemic effects, competitor behavior, individual customer histories, partner reactivation and operational optimization decisions are outside the formal boundary.

The causal analysis is presented sequentially. Figure 2 describes the partner-activation subsystem, Figure 3 presents the demand subsystem and Figure 4 integrates both subsystems into the complete causal-loop diagram.

Figure 2 presents the partner-activation subsystem, linking the prospective-partner pool, activation, active partners and the proposed corporate feedback.

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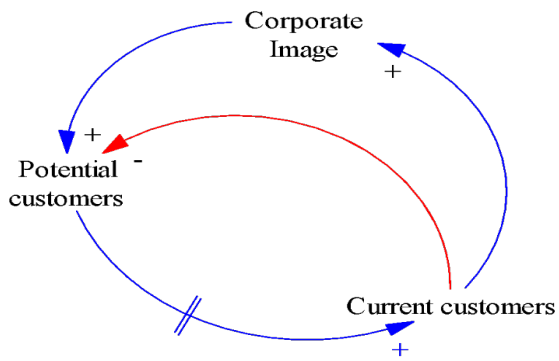


Figure 2. Causal structure of prospective-partner activation and corporate-image feedback

Activation transfers entities from the prospective-partner group to the active-partner group, creating a balancing effect because the available candidate pool is depleted as partners become active. Corporate image represents a proposed attractiveness mechanism at the conceptual level and is not quantified in the simulations.

Figure 3 presents the demand subsystem, in which retail, conventional wholesale, online and partner-related demand contribute to total monthly demand.

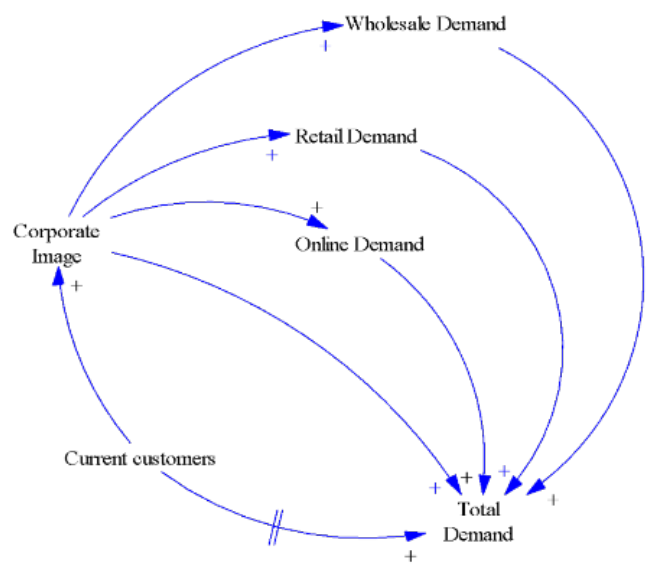


Figure 3. Causal structure of channel demand and corporate-image feedback.

The numerical formulation calculates demand from the channel values, the active-partner stock, demand per partner, and the sales-transition assumption. Corporate image and reputation remain conceptual influences and are not used to calculate the reported trajectories.

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Figure 4 combines the partner-activation and demand subsystems in the integrated causal-loop diagram used as the conceptual basis for the stock-and-flow model.

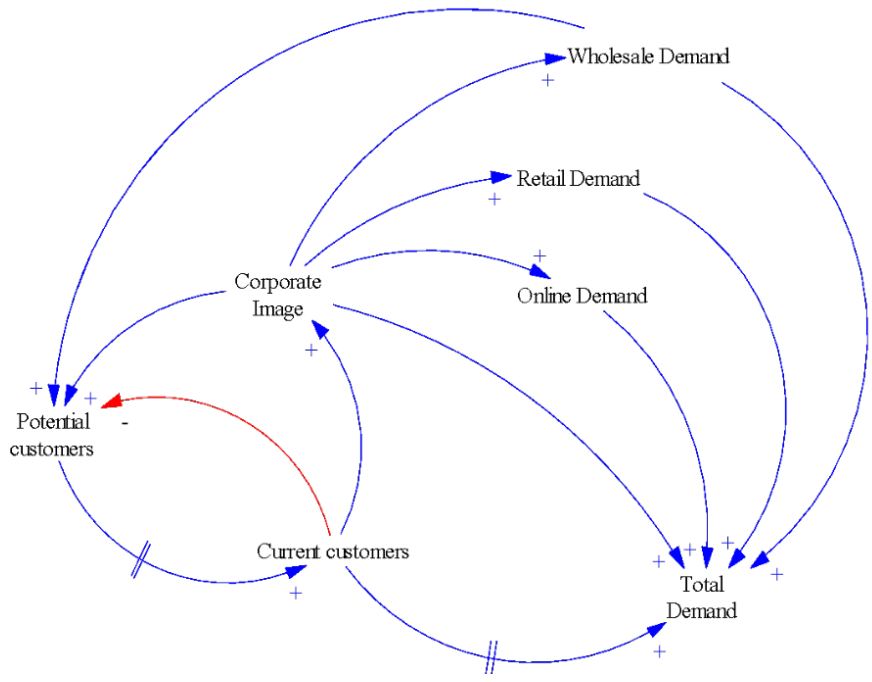


Figure 4. Integrated causal-loop diagram of partner-network expansion and demand.

The integrated diagram connects candidate generation, partner activation, active participation, channel demand and the proposed image-related feedback, Only the relationships represented in the stock-and-flow formulation are quantified in the simulations.

In the causal representation, positive polarities indicate that an increase in the source variable produces, ceteris paribus, a change in the same direction in the target variable; negative polarities indicate an opposite-direction response. The activation loop is balancing because conversion of prospective partners increases active partners while depleting the prospective pool. Corporate image and reputation are included in the conceptual representation but are not quantified as independent stocks or used to calculate the reported simulation outcomes.

Stock-and-Flow formulation

The stock-and-flow formulation contains two partner stocks and one demand stock. A fractal partner is an independent wholesale customer or commercial establishment that may join the company's distribution network through a collaborative commercial arrangement; it is neither a company-owned branch nor necessarily a formal franchise. Prospective partners are identified candidates that have not yet completed activation. Active partners have accepted or formalized the arrangement, satisfied the applicable technical, commercial, and logistical requirements, and began purchasing and commercializing the company's products.

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A candidate becomes active only after the collaborative arrangement has been accepted or formalized, the relevant requirements have been met, and commercial activity has begun. Active-partner withdrawal represents termination of the arrangement, cessation of purchasing or network activity, or failure to maintain the applicable requirements. A withdrawn business may continue as a conventional wholesale customer, but the model removes its incremental partner-related demand and treats network withdrawal as a definitive exit; individual reactivation is not represented.

The 25 unit/month wholesale component represents aggregate conventional wholesale demand. Thus, conventional purchases by former network partner remain conceptually included in the wholesale baseline without individual tracking. Monthly demand is modeled as an auxiliary rate, whereas cumulative demand is the integral of that rate, ensuring dimensional consistency between the two measures.

Figure 5 presents the stock-and-flow structure governing the movement from prospective to active partners and the subsequent withdrawal of active partners.

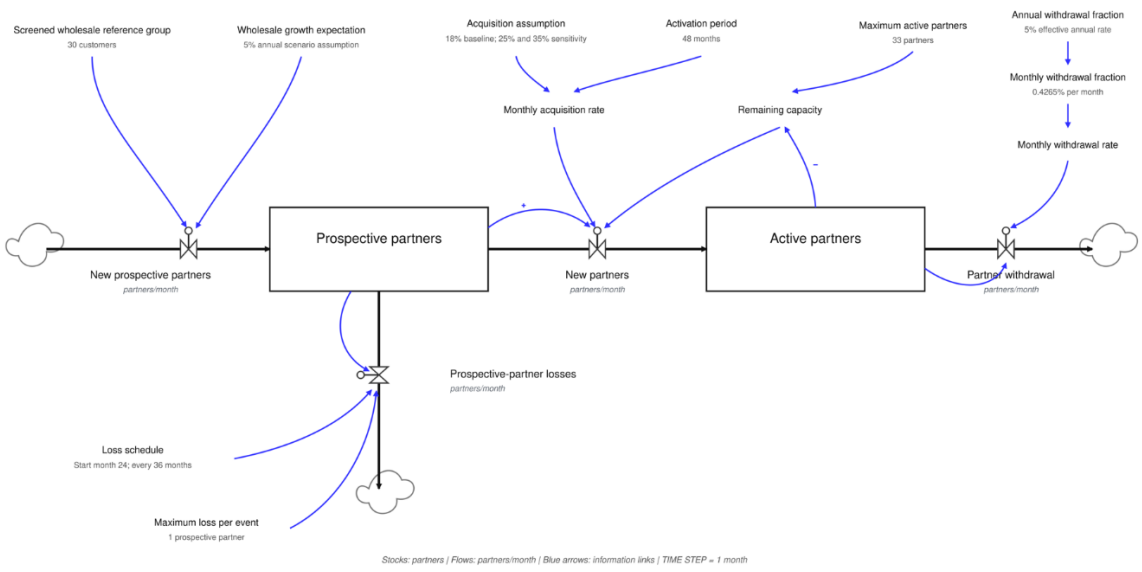


Figure 5. Stock-and-flow structure of prospective-partner activation and active-partner withdrawal

Prospective partners increase through candidate entry and decrease through activation and pre-activation losses. Active partners increase through activation and decrease through withdrawal, while remaining organizational capacity constrains further activation.

Figure 6 presents the demand structure, linking base-channel demand and active-partner demand to monthly demand and its accumulation over time.

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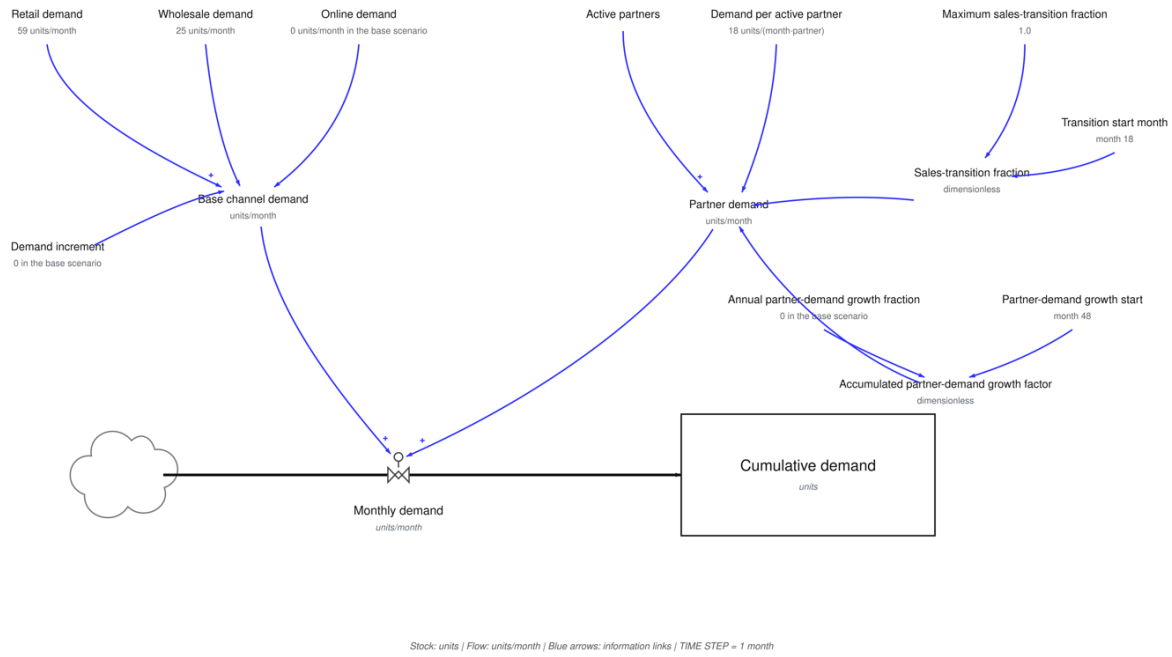


Figure 6. Stock-and-flow structure of channel-specific monthly demand and cumulative demand.

Monthly demand is represented as a rate measured in units per month and is integrated into cumulative demand measures in units. This separation maintains dimensional consistency and distinguishes current demand intensity from accumulated demand over the simulation horizon.

Together, Figures 5 and 6 define the simulated boundary: the partner stocks and flows determine network participation, while the demand structure translates that participation and the channel assumptions into monthly and cumulative demand. To complement the graphical representation, Table 1 defines the principal state and demand variables included in the model. The distinction among stocks, auxiliary rates, and reporting variables is relevant because each category performs a different function in the simulation. Prospective partners, active partners and cumulative demand retain information over time, whereas monthly demand and annualized demand are calculated for operational and reporting purposes.

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Table 1. Principal stocks and their definitions

Variable	Type and unit	Definition
Prospective partners	Stock; partner	Independent wholesale customers or establishments identified as candidates but not yet operationally activated.
Active partners	Stock; partner	Independent businesses operating in the proposed network after agreement, qualification, and commencement of commercial activity.
Cumulative demand	Stock; unit	Integral of monthly demand over the simulation horizon.
Monthly demand	Auxiliary rate; unit/ month	Retail, conventional wholesale, online, and incremental active-partner demand generated during month t.
Annualized demand	Reporting rate; unit/ year	Twelve times current monthly demand; not an independent stock or flow.

As shown in Table 1, the model contains three stocks that preserve the system state over time. Monthly demand is not treated as a stock but as the rate entering cumulative demand, while annualized demand is included exclusively as a reporting variable and does not alter the simulated system structure.

Changes in the model stocks occur through the flows summarized in Table 2. Candidate entry and pre-activation losses modify the prospective-partner stock; partner activation transfers entities from the prospective-partner stock to the active-partner stock; and partner withdrawal reduces active network participation. Monthly demand constitutes the inflow accumulated in the cumulative-demand stock.

Table 2. Principal flows and definitions

Flow	Unit	Definition
New prospective partners	partner/month	Entry events from the screened wholesale-customer reference group.
New partners	partner/month	Operational activation, constrained by the available prospective pool, acquisition assumption, remaining capacity, and 48-month window.
Prospective-partner losses	partner/month	Candidate failure or abandonment before activation, without allowing a negative stock.
Partner withdrawal	partner/month	Exit from active network participation due to agreement termination, cessation of network activity, or failure to maintain requirements.
Monthly demand	unit/month	Rate accumulated into cumulative demand.

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Equations and dimensional specification

Following the structural definitions presented in Tables 1 and 2, Table 3 provides the core equations used in the deterministic simulation. The equations specify the accumulation processes, stock-transfer relationships, capacity restriction, partner-demand formation and conversion of monthly demand into cumulative and annualized measures. The MAX and MIN functions impose non-negativity, candidate-availability, and organizational-capacity restrictions

Table 3. Core equations of the deterministic model

Variable	Equation	Unit
Prospective partners	INTEG(New prospective partners − New partners − Prospective-partner losses, 11)	partner
Active partners	INTEG(New partners − Partner withdrawal, 3)	partner
Remaining capacity	MAX(0, 33 − Active partners)	partner
Monthly acquisition rate	IF THEN ELSE(Time < 48, 0.18/TIME STEP, 0/TIME STEP)	1/month
New partners	MIN(Monthly acquisition rate × Prospective partners, MIN(Prospective partners/TIME STEP, Remaining capacity/TIME STEP))	partner/month
Monthly withdrawal fraction	1 − (1 − 0.05)^(1/12) = 0.004265	dimensionless
Partner withdrawal	MIN(Monthly withdrawal fraction × Active partners/ TIME STEP, Active partners/TIME STEP)	partner/month
Base channel demand	MAX(0, (Retail demand + Wholesale demand) × (1 + Demand increment) + Online demand)	unit/month
Partner demand	Sales-transition fraction × Demand per active partner × Active partners × Accumulated partner-demand growth factor	unit/month
Monthly demand	Base channel demand + Partner demand	unit/month
Cumulative demand	INTEG(Monthly demand, 0)	unit
Annualized demand	12 months/year × Monthly demand	unit/year

The equations maintain dimensional consistency by expressing partner stocks in partners, partner flows in partners per month, monthly demand in units per month and cumulative demand in units. The New partners flow is deducted from prospective partners and simultaneously added to active partners, thereby preserving stock-and-flow accounting consistency. Annualized demand is a reporting rate and does not constitute an additional stock.

Data treatment and assumptions

Historical inputs were constructed as monthly averages from commercial records stored in the company's enterprise ERP system for 2017-2019. Retail demand (59 units/month) was derived

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from historical retail sales and processed by the technical team for consistency with the modeled scope. Wholesale demand (25 units/month) was derived from historical wholesale sales after selecting customers or transactions comparable to the case. Demand per active partner (18 units/[month-partner]) combined historical purchasing behavior of comparable wholesale customers, aggregated information from the relevant product categories and multidisciplinary technical review. The company had no online sales in the reference period; online demand is therefore zero in the reported runs. The model nevertheless includes online channel because it formed part of the prospective commercial strategy considered during the pandemic period. These demand inputs are summarized in Table 4.

The historical values were aggregated from product categories considered pertinent to the numerical case. The original disaggregated database is unavailable, so the exact categories and SKUs included in each average cannot now be reconstructed. The values are therefore treated as case-specific historical references, not probability distributions, portfolio-wide estimates, or future-demand forecasts.

The initial conditions of 11 prospective partners and 3 active partners combined commercial information available at project inception, company identification of existing and candidate partners, and multidisciplinary technical assessment. The values were agreed through internal discussion and management acceptance. They are case-specific starting conditions rather than statistical market estimates.

The maximum of 33 active partners is an expert-informed coverage and organizational-capacity ceiling based on assessed company capabilities and prospective expansion in western Colombia, including the Coffee Region and Antioquia. It is not an optimized capacity or a count of the total market. The screened reference group of 30 prospective wholesale customers was drawn from a database of approximately 300 active wholesale customers and identified by the technical team and management as commercially plausible candidates.

The 5% annual effective withdrawal assumption was established through multidisciplinary technical discussion, consensus, and management acceptance and converted to a monthly fraction as $1 - (1 - 0.05) ^ (1/12) = 0.004265$. The STEP (1,18) transition represents activation of 100% of the modeled partner-demand component at month 18 as a project milestone; it is a structural simplification, not an empirically estimated adoption curve. Potential-partner losses represent technical-team estimates of candidate failure or abandonment before activation and are modeled as up to one loss every 36 months beginning at month 24.

Taken together the historical demand inputs, initial conditions, organizational-capacity ceiling, and expert-informed assumptions define the deterministic baseline of the model. Table 4 summarizes the principal values, units, and evidentiary basis used in the simulation.

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Table 4. Principal inputs used in the deterministic baseline simulation

Parameter	Value	Unit	Basis and evidentiary status
Retail demand	59	unit/month	2017–2019 monthly average derived from retail sales records stored in the Siesa Enterprise ERP system and processed for consistency with the case scope.
Wholesale demand	25	unit/month	2017–2019 monthly average derived from ERP wholesale sales records after selecting comparable customers or transactions.
Online demand	0	unit/month	The company had no online sales during 2017–2019; the prospective channel was retained in the model structure.
Demand per active partner	18	unit/(month·partner)	ERP-informed average based on comparable wholesale customers, aggregated relevant product categories, and multidisciplinary technical review.
Initial prospective partners	11	partner	Commercial information available at project inception, identified candidates, multidisciplinary assessment, and management acceptance.
Initial active partners	3	partner	Existing partners identified at project inception and reviewed through multidisciplinary technical discussion.
Maximum active partners	33	partner	Expert-informed organizational-capacity and prospective-coverage ceiling; it does not represent optimized capacity or the total market.
Screened wholesale reference group	30	customer	Candidate subset selected from a database of approximately 300 active wholesale customers.
Baseline acquisition assumption	18%	1/month	Business-scenario assumption established through multidisciplinary technical discussion and management acceptance; 25% and 35% were used in the sensitivity analysis.
Annual effective withdrawal fraction	5%	dimensionless	Assumption established through multidisciplinary consensus and management acceptance; monthly equivalent: 0.004265.
Activation window	48	month	Four-year implementation horizon defined for the company's innovation project; it is not a statistically estimated duration.

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Table 4 distinguishes between historical demand inputs derived from the company's ERP records and case-specific assumptions established through multidisciplinary technical assessment and management acceptance. The historical values characterize the reference operating conditions, whereas the initial partner stocks, capacity ceiling, acquisition assumption, withdrawal fraction, and activation window define the structural baseline of the simulation. These values are treated as case-specific inputs rather than statistically estimated population parameters or probabilistic forecasts.

Implementation and simulation settings

The model was implemented in Vensim PLE 10.4.0. Deterministic simulations used Euler integration, INITIAL TIME = 0 months, FINAL TIME = 240 months, TIME STEP = 1 month, and SAVEPER = TIME STEP. A monthly resolution was selected because historical inputs were aggregated as monthly averages and the company reviewed commercial information monthly. One run was executed per parameter setting; random seeds and stochastic replications do not apply. Numerical convergence across smaller time steps was not assessed, so results are interpreted within the fixed monthly resolution.

Model checking and validation for purpose

Model assessment was defined relative to its intended purpose of exploratory decision support and methodological demonstration. Dimensional consistency, equation verification, extreme-condition testing and multidisciplinary technical review were used to assess internal consistency and contextual plausibility. Sensitivity analysis was conducted separately to examine the response of the model to changes in the acquisition assumption. These procedures do not establish predictive accuracy, out-of-sample validity or empirical causal effects. Table 5 summarizes the structural and extreme-condition tests, the expected response in each case and the behavior observed during simulation.

Table 5. Structural and extreme-condition tests performed on the model

Test	Input/condition	Expected behavior	Observed behavior	Status
Dimensional consistency	Complete model	No unexplained dimensional or unit errors.	Vensim dimensional analysis produced no unit errors in the model equations.	Pass
Zero acquisition	Monthly acquisition rate = 0	The New partners flow remains zero, and Active partners declines only through Partner withdrawal.	The New partners flow remained zero, and Active partners declined gradually through withdrawal without becoming negative.	Pass

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Zero sales transition	Sales-transition fraction = 0	Partner demand is zero, and Monthly demand equals Base channel demand.	Partner demand was eliminated, and Monthly demand remained equal to the base channel component.	Pass
Capacity limit	Maximum active partners = 33	Partner activation stops when Remaining capacity reaches zero.	The New partners flow ceased when the capacity constraint became binding, and both partner stocks remained non-negative.	Pass
No initial prospective partners	Initial prospective partners = 0	The New partners flow is initially zero; subsequent activation can occur only after New prospective partners enter the system.	The New partners flow was initially zero and appeared only after prospective partners entered the system; the stock remained non-negative.	Pass

All tests produced the behavior expected from the corresponding model structure. Stocks remained non-negative, activation ceased when acquisition was disabled or capacity became binding, partner demand disappeared when the sales-transition fraction was set to zero and no partners were activated before prospective partners became available. These results support the internal consistency of the model for its intended exploratory purpose, but they should not be interpreted as evidence of predictive validity.

Sensitivity-analysis design

A one-at-a-time deterministic sensitivity experiment was conducted by changing only the monthly acquisition assumption. The baseline value of 18% was established as a business-scenario assumption through multidisciplinary technical discussion, consensus and management acceptance. Values of 25% and 35% were defined as exploratory sensitivity settings rather than estimated probabilities. All other model assumptions were held constant and each scenario consisted of one deterministic run. Table 6 presents the values applied in the three scenarios and identifies the parameters maintained at their baseline settings.

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Table 6. Assumptions used in the acquisition-rate sensitivity experiment.

Parameter	18% baseline	25% scenario	35% scenario	Unit/decision
Monthly acquisition assumption	0.18	0.25	0.35	1/month; applied during months 0–47
Maximum active partners	33	33	33	partner; held constant
Annual effective withdrawal fraction	0.05	0.05	0.05	dimensionless annual fraction; held constant
Sales-transition fraction	1.0 from month 18	1.0 from month 18	1.0 from month 18	dimensionless; held constant
Wholesale growth expectation	0.05	0.05	0.05	dimensionless; held constant
Deterministic runs	1	1	1	one run per scenario

As shown in Table 6, the acquisition assumption was the only parameter modified across scenarios. The capacity ceiling, withdrawal fraction, sales-transition structure and wholesale growth expectation remained unchanged. Consequently, differences among the simulated trajectories can be attributed to the acquisition assumption within the defined model structure, although they should not be interpreted as probabilistic confidence intervals or forecasts.

Results

Baseline behavior

Under the 18% baseline, monthly demand remained at 84 units/month through month 17: 59 units/month from retail, 25 units/month from conventional wholesale customers and zero online demand. The STEP (1, 18) sales-transition assumption then activated the full modeled partner-demand component, not all real purchases or an exclusivity condition. Monthly demand reached 347,59 units/month at month 48 and subsequently declined as activation ceased and withdrawal reduced the active-partner stock. This trajectory is a conditional model result rather than a forecast. Figure 7 displays this baseline trajectory and its change at the month-18 transition point.

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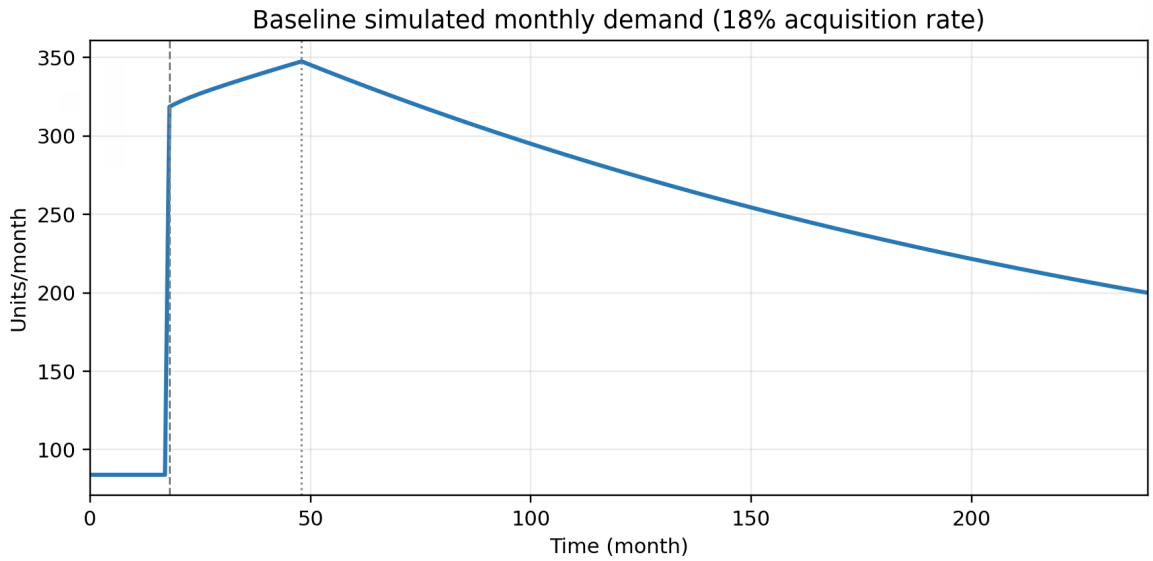


Figure 7. Baseline monthly-demand trajectory under the 18% acquisition assumption

The trajectory remains at the 84-unit/month base-channel level through month 17, increases when the modeled partner-demand component is activated at month 18, reaches its maximum near the end of the activation period, and subsequently declines as withdrawal continues without additional activation.

Acquisition-rate sensitivity

Figure 8 compares active partners, prospective partners, monthly demand and cumulative demand under the 18%, 25% and 35% acquisition assumptions.

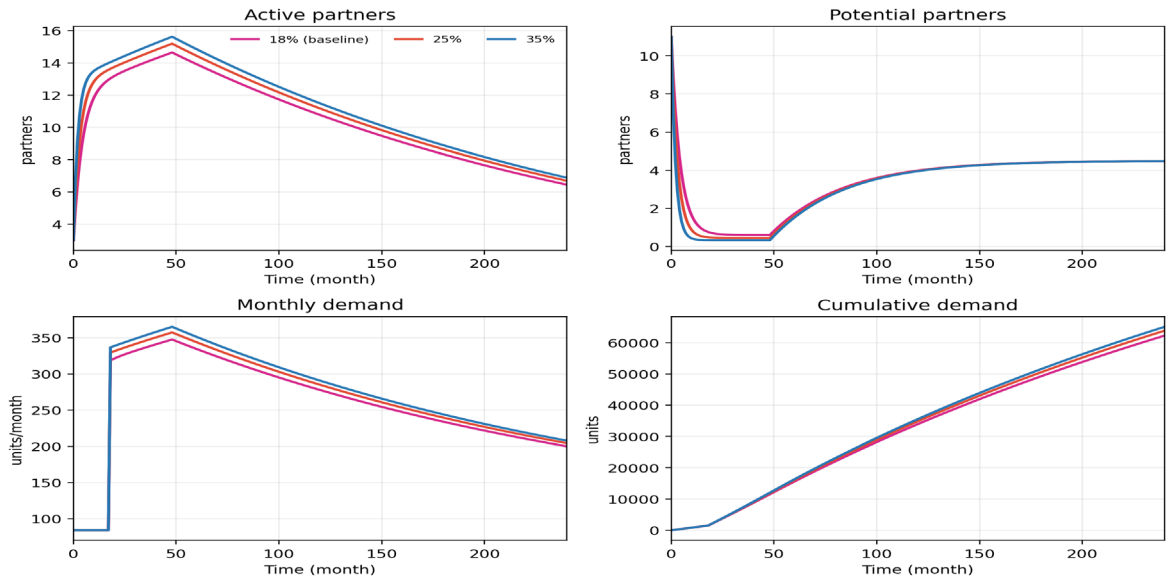


Figure 8. Sensitivity of active partners, prospective partners, monthly demand and cumulative demand to the acquisition assumption.

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The four panels show ordered responses to the acquisition assumption. Differences emerge during the activation window and narrow after month 48 as activation ceases, the prospective-partner pool is depleted, and active-partner withdrawal continues.

The graphical comparison indicates a positive but less-than-proportional response to higher acquisition assumptions. Table 7 reports the corresponding values at months 48, 120 and 240 and quantifies the differences relative to the baseline.

Table 7. Sensitivity of simulated demand to the customer-acquisition rate.

Acquisition rate	Active partners M48	Demand M48	Δ vs. base	Demand M120	Δ vs. base	Demand M240	Δ vs. base	Cumulative M240	Δ vs. base
18% baseline	14.64	347.59	—	277.76	—	200.01	—	62,253.10	—
25%	15.19	357.43	2.83%	284.99	2.60%	204.34	2.16%	63,833.30	2.54%
35%	15.62	365.21	5.07%	290.72	4.66%	207.77	3.88%	65,077.80	4.54%

At month 48, increasing acquisition from 18% to 25% and 35% increases active partners by 3.76% and 6.69%, and monthly demand by 2.83% and 5.07% respectively. The relative demand response decreased over time: at month 240 it was 2.16% and 3.88% while cumulative demand was 2.54% and 4.54% above baseline. The attenuation results from the limited potential-partner pool, the 33-partner capacity constraint, closure of the acquisition window after month 48, and continuing withdrawal. This provides evidence of parameter sensitivity within the model, but not of predictive validity or real-world causal effects. Figure 9 isolates the cumulative-demand trajectories produced by the three acquisition assumptions over the 240-month analytical horizon.

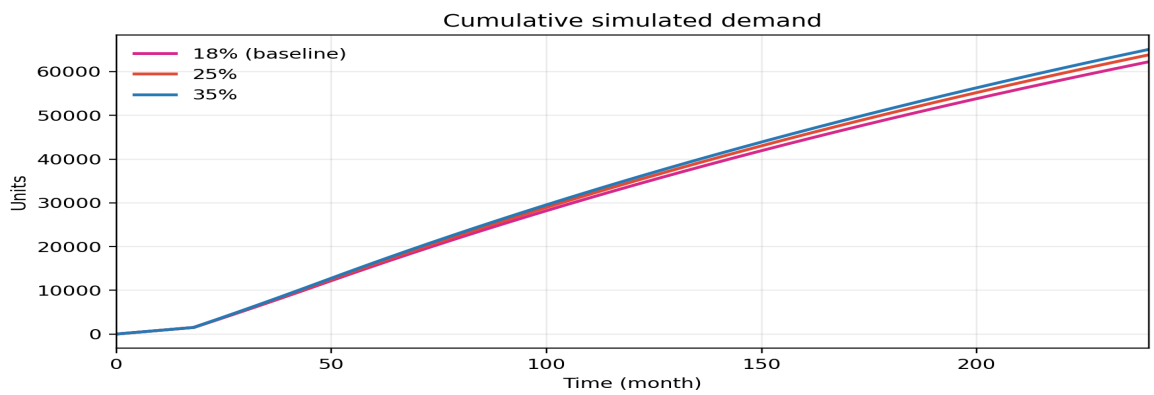


Figure 9. Cumulative-demand trajectories under the 18%, 25%, and 35% acquisition assumptions.

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The trajectories separate progressively because monthly differences accumulate over time; however, the rate of separation moderates as active-partner growth and withdrawal continues. At month 240 cumulative demand reaches 62,253.10 units in the baseline, 63,833.30 units in the 25% scenario, and 65,077.80 units in the 35% scenario. These values express conditional model behavior under the stated assumptions and do not represent observed or forecast sales.

Discussion

The simulations show a coherent mechanism. Faster activation increases active partners and partner-related demand, but the response weakens as the prospective-partner pool is depleted and the 48-month activation period ends (Figures 7 and 8). Over the extended analytical horizon, active partners and monthly demand converge toward lower trajectories under continuing withdrawal. The 240-month simulation window was used to observe long-term model behavior and should not be interpreted as a formal twenty-year corporate plan or sales forecast. The quantitative results further qualify the managerial interpretation. Increasing the monthly acquisition assumption from 18% to 35% produces a 5.07% increase in monthly demand at month 48 and a 4.54% increase in cumulative demand at month 240 (Table 7; Figures 8 to 9). The response is therefore positive but less than proportional. Within the model boundary, a higher acquisition assumption alone cannot sustain accelerating growth unless the prospective-partner pool is replenished and the withdrawal and sales-transition conditions remain favorable.

Demand-side uncertainty provides a conceptual connection with previous research on strategic flexibility under demand variation (22) and on the interaction of organizational capabilities when responding to demand-side change (23). In the present case, these studies support the strategic framing of the simulation, but flexibility and adaptive capability were not measured empirically. The relationship with dynamic capabilities must therefore be interpreted conceptually. System dynamics can support the articulation of assumptions, examination of feedback mechanisms and comparison of conditional scenarios (10, 24-26). Such use may inform managerial processes associated with business-model adaptation and organizational reconfiguration (6,27). However, this study did not measure sensing, organizational reconfiguration, technology adoption, profitability, firm performance or competitive advantage and therefore does not demonstrate changes in those constructs.

Similarly, the simulations do not optimize distribution-center location, facility design, fleet size, personnel or inventory policies. Monthly and cumulative demand trajectories could instead serve as inputs to subsequent capacity and logistics models. This distinction separates the direct evidence generated by the model from potential applications that require additional data, constraints, objectives and decision criteria.

Compared with previous system-dynamics-applications to long-term supply-demand and resource-planning problems (24,26), this case emphasizes commercial-network expansion through prospective and active partner stocks. Its applied contribution lies in making the activation, capacity, withdrawal, sales-transition and demand assumptions explicit and examining their consequences over time. The evidence remains bounded to one company, aggregated historical averages, case-specific assumptions and the absence of post-implementation observation for predictive comparison.

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Limitations and future research

This study has several limitations. First, it is based on one anonymized medium-sized Colombian hardware and construction-product distributor, limiting transferability. Second, the historical information covers 2017-2019 and cannot establish predictive accuracy over 240 months. Third, the extended horizon may contain structural breaks associated with economic cycles, technological change, pandemics, competition and regulation that are outside the model boundary. Fourth, the original transaction-level ERP dataset and calculation sheets could not be recovered; therefore, the precise SKU and category-level composition of the aggregated averages cannot be reconstructed. Fifth, although the company managed approximately 14,000 SKUs across 14 commercial lines, the numerical case does not claim portfolio-wide representativeness and is presented as an anonymized case-based methodological demonstration. Sixth, acquisition, withdrawal, capacity, sales transition, growth and initial conditions combine available commercial information with case-specific technical and managerial judgment. Seventh, multidisciplinary review supports contextual plausibility but does not constitute independent validation. Eighth, the fixed monthly formulation was not tested for numerical convergence at smaller time steps. Ninth, the sensitivity experiment varies one parameter at a time and does not quantify uncertainty. Tenth, post-implementation data were unavailable, precluding calibration against subsequent outcomes, holdout testing or calculation of predictive-error metrics. Eleventh, withdrawal is represented as definitive exit from the network even though a business could later be reconsidered, individual reactivation is outside the boundary. Finally, extreme-condition and structural tests support internal consistency for exploratory use but do not establish empirical or predictive validity.

Future research should collect prospective partner-level and transaction-level observations, preserve reproducible aggregation procedures, compare simulated trajectories with longitudinal implementation outcomes, distinguish temporary inactivity from permanent withdrawal and reactivation, examine joint parameter uncertainty and connect demand trajectories to explicit capacity, inventory, facility and fleet decision models.

Conclusions

The model provides an internally consistent representation of how a screened prospective-partner pool, activation, capacity, withdrawal, sales transition and channel demand interact in the anonymized commercial-expansion case. Monthly demand is represented as a rate and accumulated in a separate stock, maintaining dimensional consistency. The documented dimensional and extreme-condition tests produced the expected results. Within the deterministic sensitivity experiment, higher acquisition assumptions increased active partners and demand, but the effect diminished after month 48. Relative to the 18% baseline, the 25% and 35% scenarios increased cumulative demand at month 240 by 2.54% and 4.54% respectively. These outcomes indicate diminishing marginal effects under a restricted prospective-partner pool and fixed remaining assumptions.

The model should be used as an exploratory decision-support and methodological demonstration tool rather than a validated twenty-year forecast. Its trajectories may support multidisciplinary discussion

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and subsequent logistics and capacity analyses, but they do not demonstrate the effectiveness of technology adoption, automatic replenishment, distribution center design, fleet acquisition, hiring, inventory optimization or overall supply chain performance.

CRediT authorship contribution statement

Conceptualization - Ideas: Diego León Peña Orozco. Data curation: Diego León Peña Orozco, Andrés Mauricio Paredes Rodríguez. Formal Analysis: Diego León Peña Orozco, Mauricio López Orozco, Andrés Mauricio Paredes Rodríguez. Investigation: Diego León Peña Orozco, Mauricio López Orozco, Andrés Mauricio Paredes Rodríguez. Methodology: Diego León Peña Orozco, Mauricio López Orozco, Andrés Mauricio Paredes Rodríguez. Project Management: Diego León Peña Orozco, Andrés Mauricio Paredes Rodríguez. Resources: Diego León Peña Orozco, Mauricio López Orozco, Andrés Mauricio Paredes Rodríguez. Supervision: Diego León Peña Orozco. Validation: Diego León Peña Orozco, Mauricio López Orozco, Andrés Mauricio Paredes Rodríguez. Writing - original draft - Preparation: Diego León Peña Orozco, Mauricio López Orozco. Writing - revision and editing - Preparation: Diego León Peña Orozco, Mauricio López Orozco, Jesús González-Feliu.

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