MODEL FOR CALCULATING OPERATIONAL CAPACITIES IN SERVICE PROVIDERS USING SYSTEM DYNAMICS

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Abstract — *In this article establishes the allocation study importance for the workforce in the service industry, focusing on credit companies in the financial sector, given its complexity and the relationship between the operational capacity determination in offices, in relation with fluctuations in transactional demand of system. Based on historical data and system behavior using statistical analysis, was simulated the transactional demand and profitability behavior. Once defined the model for calculating operational capacity, and supported on system dynamics model was constructed a continuous simulation that calculates the resources number (workforce, workstations and ATMs) required to serve the services demand and looking for the maximum use of available capacity, formulated as a proposal not only for credit companies, also for service companies with similar settings and want to evaluate the allocation of these resources with variable demand in a particular or general sector of the system.*

***Keywords* —** capacity planning, model, services, financial sector, system dynamics.

INTRODUCTION

The capacity planning is one of the critical elements in business decisions at any level, through proper configuration and allocation is achieved respond to changing market needs. In the process of planning and scheduling capabilities of goods and services systems, as in most of the decisions in the field of Industrial Engineering, is impossible to put aside the costs associated with a configuration or another. Thus, the relationship between the resource allocation and response to customer requirements is the basis of the models used in the processes related to the capacities in these systems.

The demand for services in the world and in Colombia has been growing over the past twenty years, growth that goes along with resource requirements associated with its provision and the need for appropriate settings on your assignment, given the particularities in processes of service delivery as seen in the models applied to capacity planning in the sector.

The capacity planning models studied are based on the application in the manufacturing industry, service industry applications are mainly in logistics, transportation, communications and utilities. The model developed in this research was based on the study of the detection of operational capacity requirements from the perspective of the work force and workstations allocation, from information provided by a Colombian banking company, given its important role in the national and world economy.

The review of the main capacity models existing, allows considered the elements for resource planning in the services provision, particularly the models used in system dynamics are not consider the resources allocation studied in this research, such as the shift analysis, tellers and business advisors, workstation per process and ATMs (Automatic Teller Machines).

1. SERVICES INDUSTRY

Based on statistics from the WTO [1] found that the service sector in the world has experienced exponential growth in billions of dollars, by the period between 1980 and 2011, corresponding with the correlation coefficient of 0.9856 for exports and 0.9804 in the case of imports (see Figure 1).

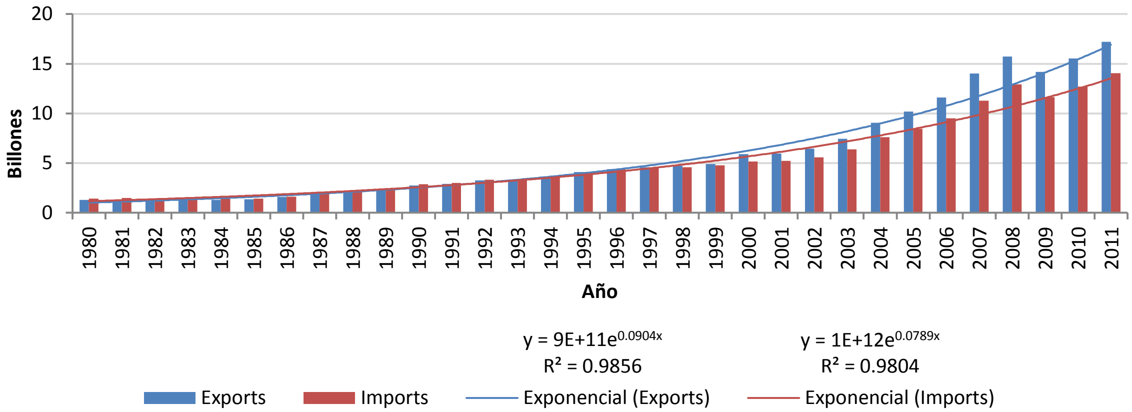


***Figure 1**. Services trade balance in the world between 1980 and 2011*

In the period between 1980 and 2011 the service sector in Colombia as WTO has grown exponentially in billions of dolars, corresponding with the correlation coefficient of 0.8383 in the case of exports and 0.953 for the case of imports (see Figure 2).

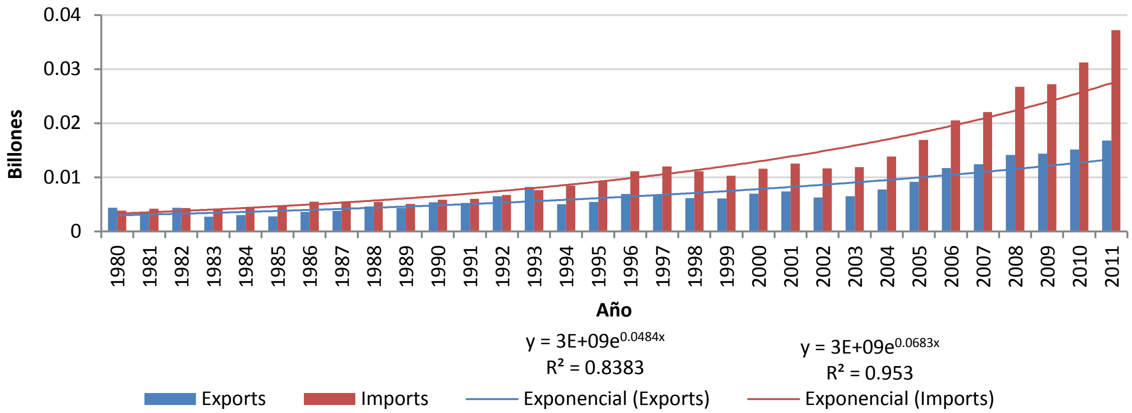


***Figure 2**. Services trade balance in the Colombia between 1980 and 2011*

The National Bureau of Statistics of Colombia (DANE) presented the analysis of the Colombian economy during the first quarter of 2012 [2], the behavior of GDP by industry groups and specifically the financial sector. Comparing with the same quarter last year, the sectors with the highest growth were the mining and quarrying (12.4%) and the service industry, with the financial institutions, insurance, real estate and business services (6.7%). In 2012 the Annual Survey of Services 2010 (EAS) [2] which includes 5,343 companies, shows the total staff employed 346,371 people, the percentage of people employed by service companies corresponds to 21.6%, compared with 31.3% manufacturing industry , indicating the importance of the service sector participation in the generation of employment in Colombia.

The Financial Superintendence of Colombia presented the profits of the major sectors that compose the Colombian financial system, the highest profit percentage (23.6%) [3] recorded the credit institutions, sector in which the company supplier of information for model development is located.

2. MODELS APPLIED TO CAPACITY PLANNING

2.1. General models for services

Regarding the employees assignment to jobs, detected models are essentially about capacities and workforce allocation. Liu, Tipper and Siripongwutikorn [4] studied reserve capacity and cost. Ningfang, Giuliano, Ludmila and Evgenia [5] consider arrival flows and service time. John, Bob, Gillian and Tom [6] incorporate variables as demand for medical services, specialty type, services time, time available and used by specialty. Abraham, Byrnes and Bain [7] include demand for hospital services and occupancy levels. Leonie and Matthew [8] factors include promotion, prevention, desired state, complications and treatments.

As queuing models and Markov chains are highlighted presented by Iftikhar, Singh, Landfeldt and Caglar [9] includes allocation of network resources and capabilities. Huang, Wang and Chang, [10] analyze bottlenecks and throughput. Jung, Hong, Chang and Lie [11] contemplated time between arrivals, call time and attention prioritization. Xiaozhu, Hui, Guofei and Haifeng [12] proposed inhomogeneous arrivals, scheduling workloads and service level. Jiang and Seidmann [13] added arrivals and service time. Casale, Mi and Smirni [14] also analyzed within the model arrivals, service times and workloads. Wang [15] presents disease conditions and changes in the queue. Palvannan and Teow [16] consider service capacity, the demand for services and timeouts.

In locating workstations and allocating resources (one of the elements on which this research focuses, is presented the model proposed by Segall [17] which takes into account staff allocated by location, potential demand, unserved demand and idle capacity. Nico, Jully and Gergely [18] analyze stochastic demand, initial budget level, cost of temporary workers and deviations from budget and one of which the FTE concept is taken (Full Time Equivalent [19]) is the proposed by White and Badinelli [20] working with number of FTEs allocated, FTEs hired, FTEs fired and customers arrivals.

For optimization models, stochastic and integer programming is located the model proposed by Fragnière, Gondzio and Yang [21] involving randomness in the volume of transactions, capacity of the skilled and unskilled workers and allocation according to that capacity. Hwang, Gao and Jang [22] include changes in demand, behavior of service quality, value for money, operational and marketing perspectives. Cheu, Lei, and Aldouri [23] consider fluctuations in demand and travel time. Netessine, Dobson and Shumsky [24] take into account flexibility in assigning specialized skills, resources adaptation, demand behavior and capacity changes on the optimal solution.

2. 2. Capacity models using system dynamics

Into the models applied in manufacturing using system dynamics is posed the model by Georgantzas [25] that considers customer service and service quality expectations and customer perception. Homer [26] analyzes workforce, customer satisfaction and the number of stations or jobs.

About logistics applications is the model laid by Senge and Rogelio [27] including service capacity, service quality, customer satisfaction and workers turnover. Edward [28] involves demand, workers and capacity requirements. Anderson. Morrice and Lundeen [29] also take into account demand, capacity and backorders. Becerra, Romero, Herrera and Trujillo [30] considered market requirements, workstations capacity, service agreements and workstations usage.

Within specific models for analyzing capabilities, Kalenatic [31] presents in the integral and dynamic model for the analysis, planning, scheduling and control of productive capacities in manufacturing companies. Two types of capacities, first the technical capacity determined by the system potential (maximum performance obtained), in making goods and/or services in a given time period. Second the economic capacity defined in relation to the costs associated with its operation in the defined time horizon (lower unit costs of goods and/or services performed). Additionally the capacities were classified: theoretical capacity, installed capacity, available capacity, necessary capacity and used capacity, using linear programming models for better capacity utilization.

Meanwhile, Orjuela, Huertas y Kalenatic [32] develop a specific model for services, which defines three types of capacity. The banking capacity as the number of workstations, the number of accounts opened and millions of pesos received in accordance with the products offered; bank operating capacity as the number of employees, number of accounts opened and millions of pesos received in accordance with the products offered and monetary capacity as the amount of money acquired for transactions in deposits of banking, and investments. The definitions consider various aspects, for this research will be the analysis of the capacity and the number of hours per month that the system can respond according to the resources in terms of personnel and workstations considered. Orjuela, Huertas y Kalenatic et al present a comprehensive model for managing service companies using system dynamics in the particular case of the banking sector. This model is taken as the main reference for this research.

From the review it can be said that within the capacity planning models and even services that apply system dynamics, are not considered fully the elements included in the model result of this research, specifically behavior analysis of allocated workforce and related workstations by operative processes (tellers and business advisors) and work shift (diurnal, additional and Saturday) in the fields of human resources, workstations and electronic payments in the case of ATMs (Automatic Teller Machines).

3. METHODOLOGY

The system dynamics model of this research was conducted using the iThink software. Using software, such as Microsoft Access, Microsoft Excel and StatFit, with information supplied by a Colombian bank. The methodology stars in the parameters calculation, followed by input analysis of model variables and ending with the capacities calculation.

3.1. Model parameters

For the model run, initial data were used, such as the number of workstations installed and the number of workers (tellers and business advisors), also was included in the model, the initial number of ATMs (Automatic Teller Machines) (see Table 1). The estimated time in hours per worker available in the month is done based on the hours of service per office, using the average service time per day, the percentage of 11% of supplements developed by the ILO (International Labour Organization) and the number of days worked per month. For the case of ATMs is considered that are open every day in the month from 8:00 to 20:00 hours. Time of cash provisioning and maintenance time per day are discounted, with average of 27 minutes per day (0.45 hours) (see Table 2).

Table 1. *Workstations installed, number of workers and ATMs (initial)*

Position	Shift	Locations installed	Current workers	ATMs
Tellers	Diurnal	265	253	120
	Additional		88	
	Saturday		103	
Business advisors	Diurnal	283	248	
	Additional		102	
	Saturday		81	

Table 2. *Available time in hours per month (workers and ATMs)*

Type	Shift	Hours / Day	Supplements (%) – Provisioning (hrs)	Days / Month	Available time (Hours / Month)
Workers	Diurnal	6.45	0.11	20	114.72
	Additional	4.37		20	77.80
	Saturday	4.94		4	17.58
ATMs	All day	12.00	0.45	30	346.50

Based on information from the financial company, are considered delays with a month of duration that occur in the hiring and dismissal (or relocation) of staff and in the assembly and disassembly of ATMs. Similarly, in a second scenario are considered these workforce adjustments every certain period of time (see Table 3).

Table 3. *Delays and time review*

Type	Setting	Delays (Month)	Time review (Month)
Workers	Hiring	2	3
	Dismissal	1	3
ATMs	Assembly	2	3
	Disassembly	1	3

3.2. Input analysis for model variables

3.2.1. Transactions demand for offices

For transactional demand analysis were taken from historical records of bank transactions, the databases are managed in Oracle software, thus generated a database file using Microsoft Access software and obtaining a transaction history table of 24 months with 1’315.872 records with the following fields:

- *Office:* office code.
- *Transaction:* transaction code.
- *Date:* month in which transactions were generated.
- *Shift:* is classified diurnal (morning and afternoon) additional and Saturday.
- *Quantity:* sum of transactions per date.
- *Assignment:* worker who makes transaction (teller or business advisor).

Additionally, the bank has a table with standard times per transaction (130 types of transactions in a timesheet) this table was loaded to initial Microsoft Access file. The table has the following fields:

- *Code:* transaction code.
- *Description:* transaction description.
- *Transaction type:* allocation (teller or business advisor).
- *Teller time:* minutes established standard for the teller transaction.
- *Business advisor time:* standard minutes established for the business advisor transaction.

Subsequently a query in the database was generated, in which to multiply the number of transactions (history table) by the time set in the standard timesheets, transforming this time in hours and grouping them by month. This query has the following fields:

- *Date:* month in which transactions were generated.
- *Assignment:* worker who makes transaction (teller or business advisor).
- *Shift:* is classified diurnal (morning and afternoon) additional and Saturday.
- *Demand in hours:* multiplying the number of transactions per code (Transactions / Month) by standard time defined in hours (Hrs / Transaction).

The results of this query are displayed by shift into tellers processes in Figure 3 and into business advisors processes in Figure 4.

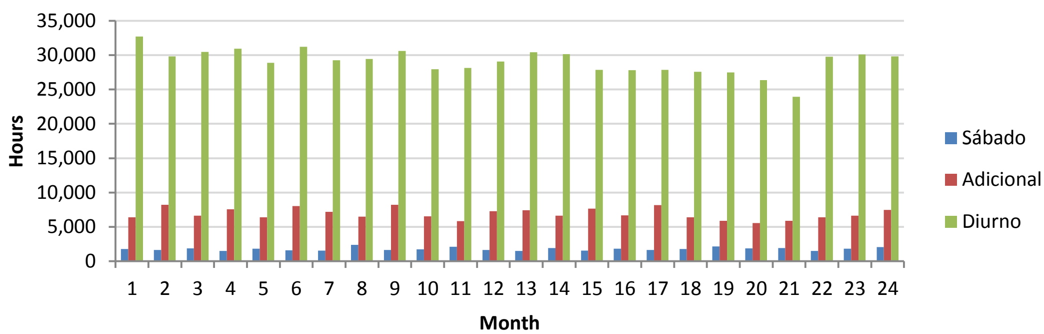


***Figure 3**. Volume of transactions for tellers process (hours demanded)*

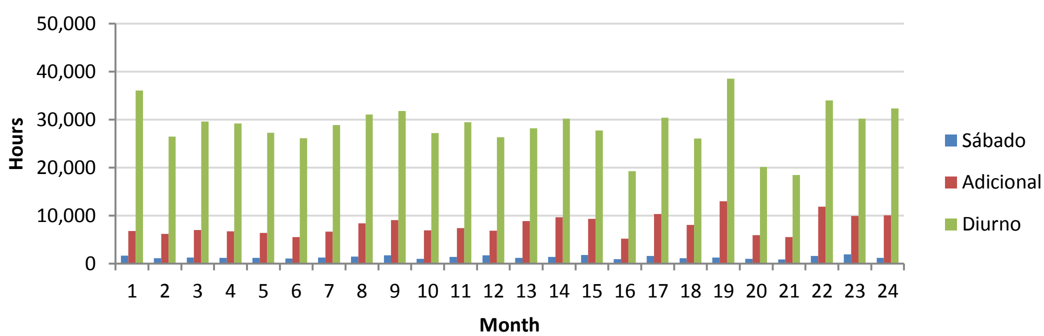


***Figure 4**. Volume of transactions for business advisors process (hours demanded)*

Within the simulation was analyzed a planning horizon of five years (sixty months), was performed by analysis of input data from the demand in hours for tellers processes and business advisors processes.

To verify the independence of the data was used StatFit statistical software, which performs two tests of independence, the runs test above / below median and turning points, using a significance level of α 0.05, cannot reject the hypothesis that the data comes from an independent distribution (see Table 4).

Table 4. *Statistical tests for independence – transactional demand*

Position	Shift	Above/Below median	Turning points
Tellers	Diurnal	1.66969	1.8462
	Additional	0.417424	0.839181
	Saturday	1.25227	0.671345
Business advisors	Diurnal	0.834847	0.335673
	Additional	1.25227	0.335673
	Saturday	1.25227	0.839181

By StatFit software were tested for goodness of fit to know the density function to fit the data, the software applies the Chi-square, Kolmogorov-Smirnov and Anderson Darling test. The results of the functions that fit the data are show in Table 5.

Table 5. *Density functions and parameters – transactional demand*

Position	Shift	Distribution	Minimum	Maximum	Mode	Alfa	Beta	p	q
Tellers	Diurnal	Weibull	13491.50	-	-	10.26	16332.60	-	-
	Additional	Triangular	5353.53	8791.61	6405.32	-	-	-	-
	Saturday	Beta	1457.24	2747.13	-	-	-	1.25	3.64

Position	Shift	Distribution	Minimum	Lambda	Gamma	Delta	Alfa	Beta	p	q
Business advisors	Diurnal	Logistic	-	-	-	-	28741.00	2460.66	-	-
	Additional	Johnson SB	5112.72	8640.12	0.66	0.72	-	-	-	-
	Saturday	Pearson 6	873.96	-	-	-	-	1699.77	3.73	13.55

With these results, the StatFit generator was used to simulate the behavior of transactional demand for five years, as input to the dynamic system model.

3.2.2. Transactions demand for ATMs (Automatic Teller Machines)

For the analysis of transactions on ATMs were taken from historical records of bank transactions, the databases are managed in Oracle software, thus generated a database file using Microsoft Access software and obtaining a transaction history table of 24 months with 12’736.230 records with the following transaction types: withdrawals, consultations, key change, services, payments and transfers, reversed transactions, cash advances, activation and declined.

Subsequently a query in the database was generated, in which to multiply the number of transactions by the standard time, transforming this time in hours and grouping them by month. The transactions of Automatic Teller Machines have had an increase over time as evidenced by the correlation coefficient of 0.536. Given this correlation, the demand for ATM was taken like the equation of the line $y = 45{,}202.14 + 890.30x$ (see Figure 5).

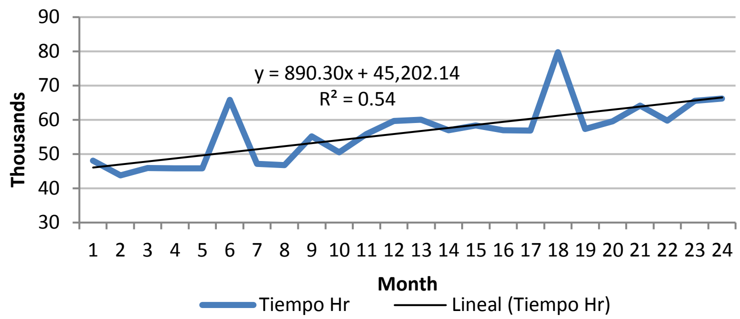


***Figure 5**. Volume of transactions at ATMs –Hours*

3.2.3. Profitability by process

For the analysis of profitability, data were taken from the historical profitability of the bank's offices in general for 24 months related with tellers and business advisors processes, provided by the Planning Department (see Figure 6).

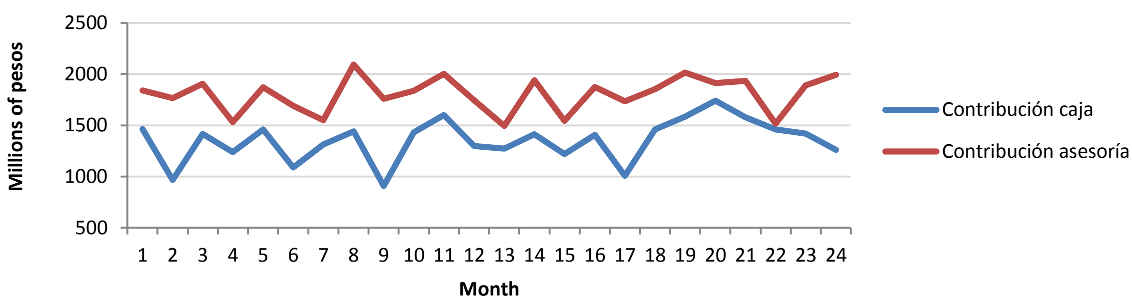


***Figure 6**. Historical profitability by process*

Similar to the analysis of demand, to verify the independence of the data was used StatFit statistical software. Using a significance level of α 0.05 cannot reject the hypothesis that the data comes from an independent distribution (see Table 6).

***Table 6.** Statistical tests for independence – profitability by process*

Process	Above/Below median	Turning points
Tellers	0.417424	0.839181
Business advisor	1.25227	0.671345

Using StatFit software was tested for goodness of fit to know the density function to fit the data. The results of the functions that fit the data are show in Table 7.

***Table 7.** Density functions and parameters – profitability by process*

Process	Distribution	Tau	Beta	Minimum	Maximum	Mode
Tellers	Triangular	-	-	8.25020E+08	1.79207E+09	1.44164E+09
Business advisor	Extreme Value	1.88758E+09	1.35397E+08	-	-	-

As mentioned, in the input analysis of transactional demands by process (tellers and business advisors) and shift (diurnal, additional and Saturday), profitability and ATMs transactions (Automatic Teller Machine) historical data twenty four (24) months were taken (July 2010 to June 2012) and to the run length of the simulation model are considered sixty (60) months. The simulated data for the variables of transactional demand, profitability and those calculated by the linear trend equation (transactions at ATMs), were loaded into a Microsoft Excel spreadsheet, in order that the iThink software loads the data and runs the model.

4. MODEL

4.1. Capacity analysis

The model focuses on behavioral analysis of the capacities for service delivery in the tellers and business advisors operations, also in the ATM services capacities analysis (ATM: Automatic Teller Machine).

- *Necessary Capacity* (Cn_{ijk})*:* number of hours demanded for the process *i*, in the shift *j* and the month *k*, equal to transactional demand in hours per process and shift per month (d_{ijk}), results of the input of variables.
- *Available capacity* (Cd_{ijk})*:* number of hours available according to the time available for the process *i*, in the shift *j*, by the month *k* and the number of workers allocated.
- *Discrepancy Capacity* (DS_{ijk})*:* difference between the Available Capacity (Cd_{ijk}) and the Necessary Capacity (Cn_{ijk}) or transactional demand (d_{ijk}).
- Available time in hours for the process *i*, in the shift *j*, by the month *k* (Td_{ijk}):

$$Td_{ijk} = h_j \times (1 - S) \qquad (1)$$

Where:
h_j: number of working hours in the shift *j*.
S: percentage of supplements established by the ILO (International Labour Organization).

- Available capacity for the process *i*, in the shift *j*, by the month *k* (Cd_{ijk}):

$$Cd_{ijk} = Td_{ijk} \times dm \times F_{ijk} \qquad (2)$$

Where:
dm: days worked for the month.
F_{ijk}: workers allocated process *i*, in the shift *j*, by the month *k*.

- *Shortage Capacity (Cf_{ijk}):* percentage of shortage capacity given in the case that transactional demand (d_{ijk}) exceeds the available capacity (Cd_{ijk}).

$$Cf_{ijk} = \begin{cases} \left(\frac{d_{ijk} - Cd_{ijk}}{Cd_{ijk}}\right) \times 100, Cd_{ijk} < d_{ijk} \\ 0 \qquad\qquad\qquad\qquad , \text{otherwise} \end{cases} \qquad (3)$$

- *Idle Capacity* (Co_{ijk})*:* percentage of shortage capacity given in the case that the available capacity (Cd_{ijk}) exceeds the transactional demand (d_{ijk}).

$$Co_{ijk} = \begin{cases} \left(\frac{Cd_{ijk} - d_{ijk}}{Cd_{ijk}}\right) \times 100, Cd_{ijk} > d_{ijk} \\ 0 \qquad\qquad\qquad\qquad , \text{otherwise} \end{cases} \qquad (4)$$

Graphical analysis of the capabilities and allocation are shown in Figure 7.

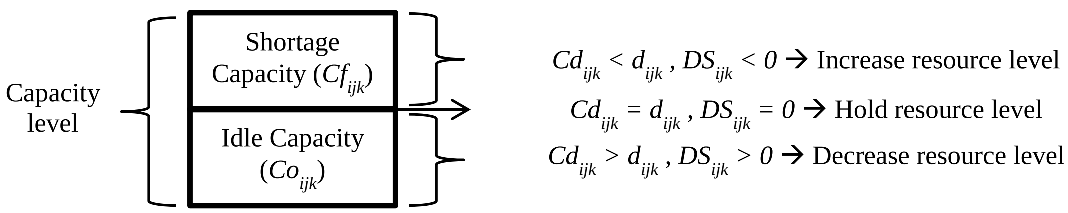


***Figure7**. Capacity levels and allocation of workers*

4.2. Problem articulation

Establishing the importance of the workforce allocation study in the service industry, specifically in credit institutions of the Colombian financial sector, given its complexity and the dynamic relationship between the operational capacity determination in offices (workers and workstations), with respect to fluctuations in transactional demand of system, which addressed the problem through system dynamics.

In the status of the art review, were found applications in manufacturing capacity models essentially approached from aggregate planning and simulation. In the case of services and system dynamics applications, there is a trend in communications applications and models applied to the allocation of workers in public services.

The capacity model presented in this research is based on the dynamic integrated model for the management of service companies using system dynamics in the banking sector, developed by Orjuela, Kalenatic and Huertas [32], specifically in the feedback system of the capacity, process, workers and workstations. This model exhibits the level required by tellers (NPTC), business advisors (NPTA) and administrative staff (NPTAD) as a measure of capacity.

4.3. Dynamic hypothesis

With the development of capacity model using system dynamics in this research, we seek to test the hypothesis which considers dynamic with variable demand, allocating appropriate levels of workers and workstations in the services; it achieves a maximum use of the resources capacity in the system.

4.4. Continuous simulation model

4.4.1. Model conceptualization

The model was based on the transactions demand study (time in hours) per shift (diurnal, additional and Saturday) to tellers processes and business advisors in offices, according to the availability of capacity in hours for these processes, given by the number of workers allocated and workstations constraints. The requirement for expansion of workstations if required by demand changes and in compliance with established return policy (allowing expansion of jobs if returns are above the yield quartile 1 per process). Finally, installing automated teller machines (ATMs) based on demand and transaction time addressing them (see Figure 8).

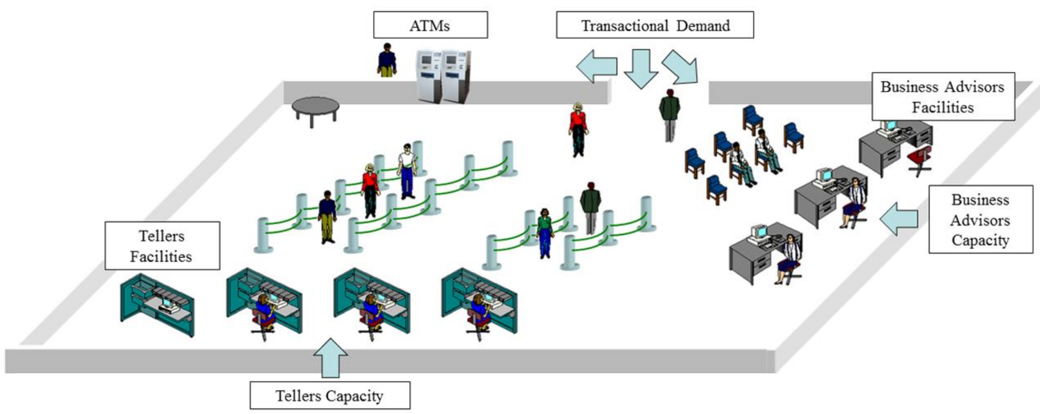


***Figure8**. Model conceptualization*

The relationships between the model components can be observed through the causal diagram (see Figure 9).

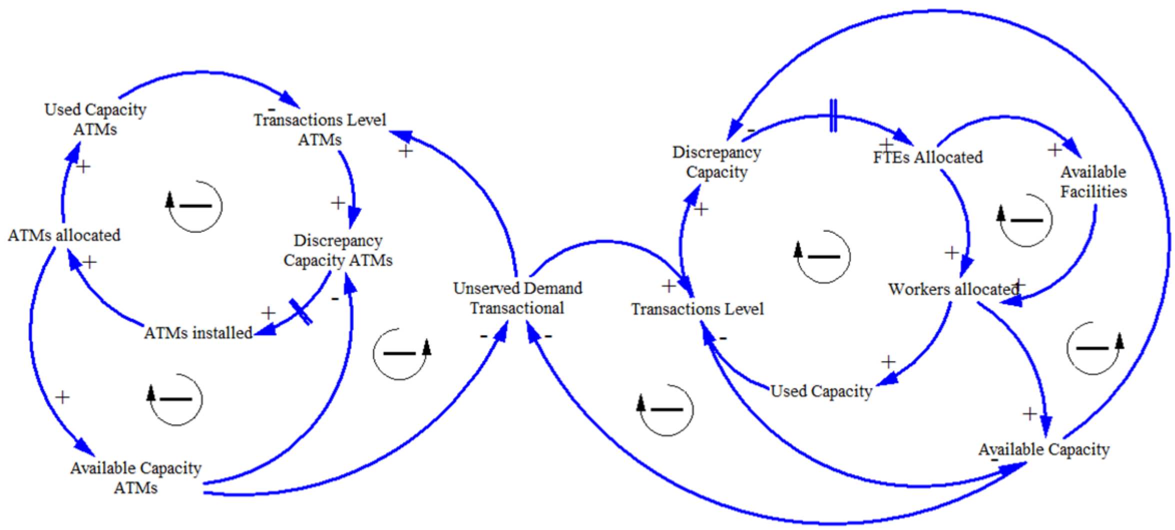


Figure9. *General causal model diagram*

Forrester diagram per sectors model shows in Figure 10.

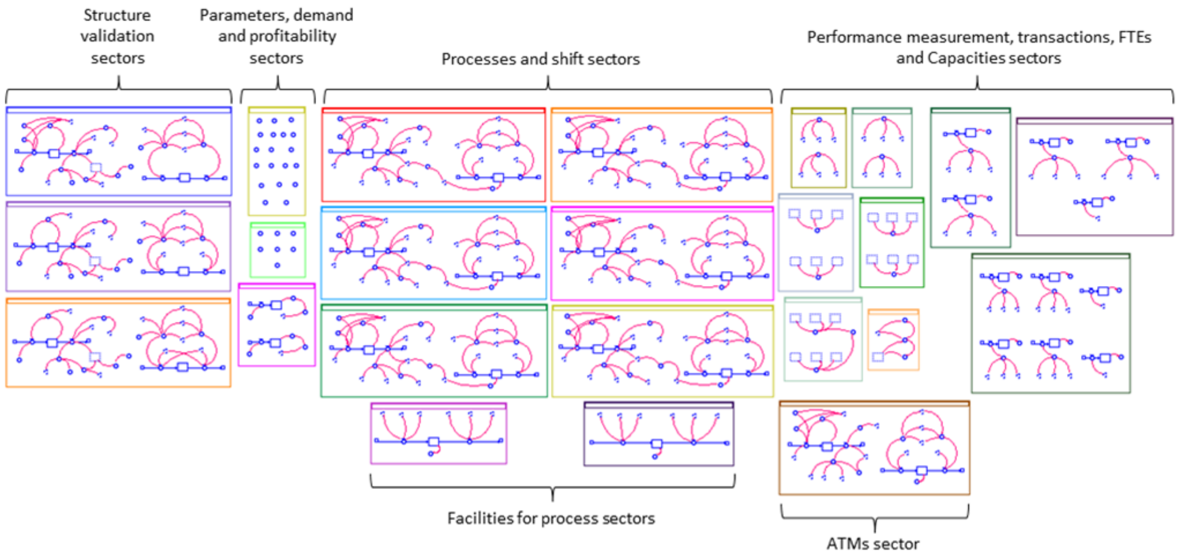


Figure10. *Forrester diagram for the capacities model*

The main sectors of the model are shown in the following paragraphs.

4.4.2. Sectors per process and shift

The six sectors per process and shift are responsible for calculating the number of workers required in accordance with changes in demand, the workstations available per process and the profitability constraint (see Figure 11).

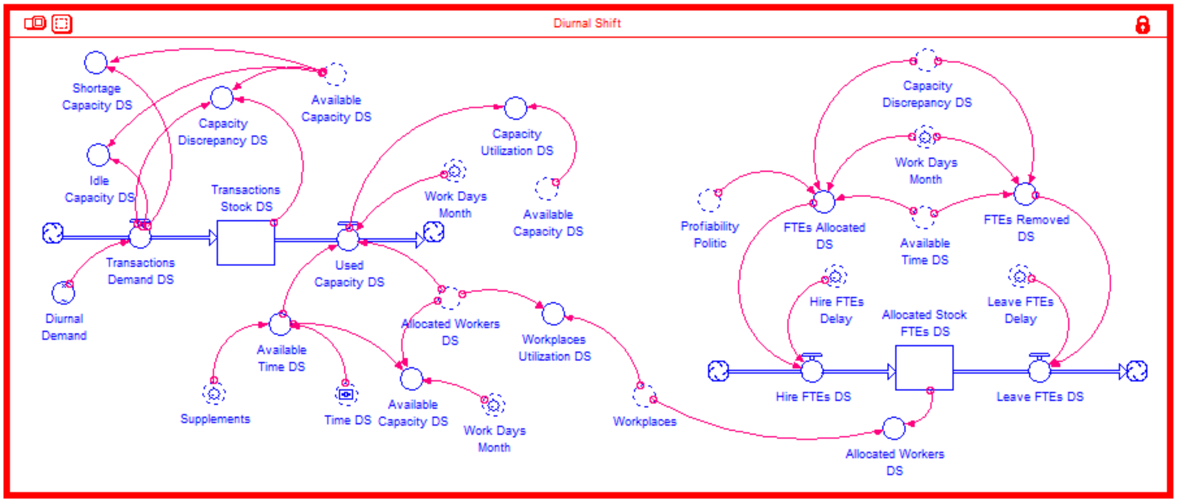


Figure11. *Forrester diagram for one of the process and shift sectors*

4.4.3. Workstations per process sectors

This sector calculates the number of workstation required for each process, as the following integer resulting from the relationship between the maximum FTES number allocated per shift and maximum FTEs number deallocated per shift. Forrester diagram for one of the workstations sectors is shown in Figure 12.

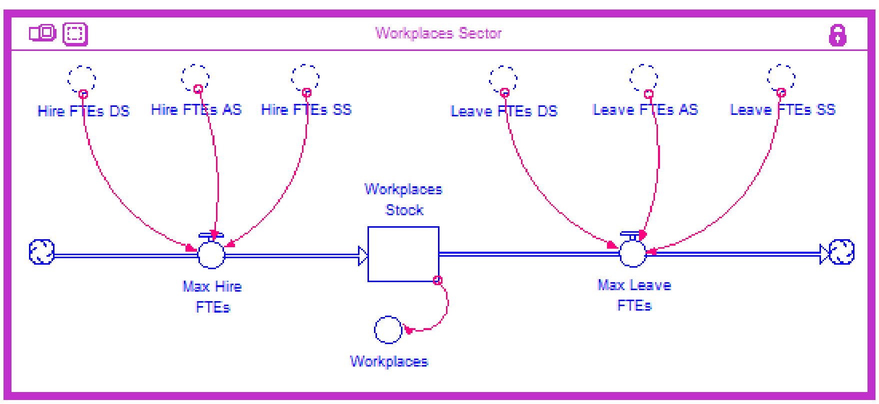


Figure12. *Forrester diagram for one of the workstations sectors*

4.4.4. ATMs sector

This sector calculates the required number of ATMs according to changes in demand (see Figure 13).

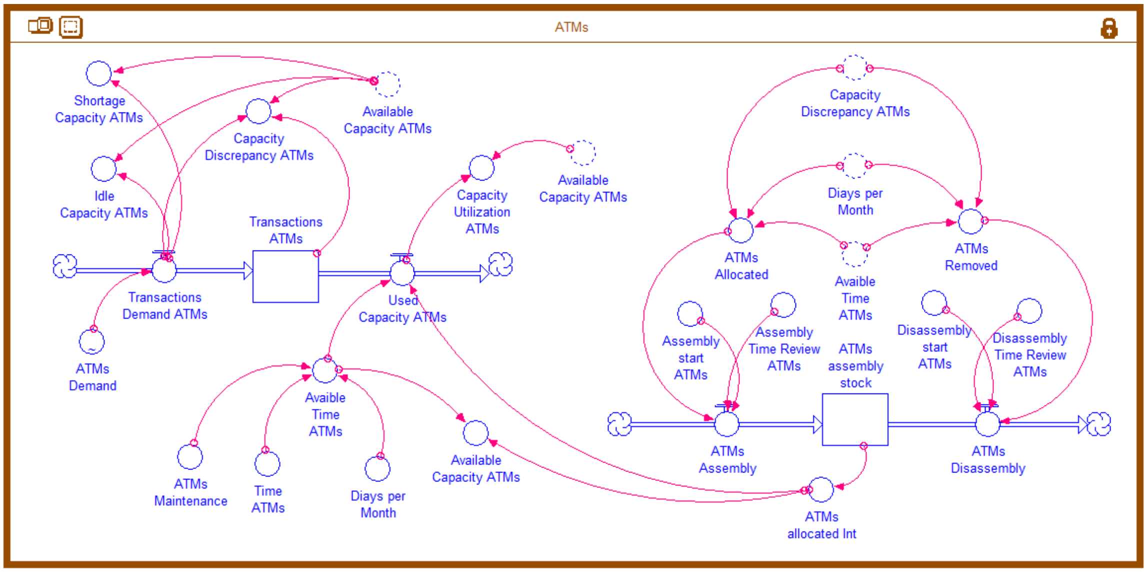


***Figure13**. Forrester diagram for ATMs sector*

4.4.5. Performance measures sectors

In order to analyze the results of the model were developed to collect her behavior sectors per way of performance measures as described below:

- *Demand Average:* computes the number of hours on average per process demand.
- *Average Transactions:* computes the average cumulative transactions per process.
- *Transactions on Office:* computes the total office for processing transactions.
- *Percentage of Transactions:* computes the percentage of total transactions that applies to offices and ATMs.
- *Workers Average:* computes the average worker number allocated per process.
- *Average FTEs Allocated:* computes FTEs average number allocated per process.
- *Workstations Utilization:* computes the averaged cumulative workstations utilization per process.
- *Capacity Utilization Average:* computes the averages accumulated utilization of the workers available capacity per process and the ATMs installed.
- *Shortage and Idle Capacity:* computes the averages accumulated workers shortage capacity and workers idle capacity per process and the ATMs installed.

4.4.6. Algorithm for allocation of workers and for the calculation of ATMs

Within the structure of the model was performed by allocating workers per process and shift in accordance with the workstations and profitability constraints. Workstations constraint referred if there are available workstations and if satisfies profitability constraint, growing workers number (see Figure 14).

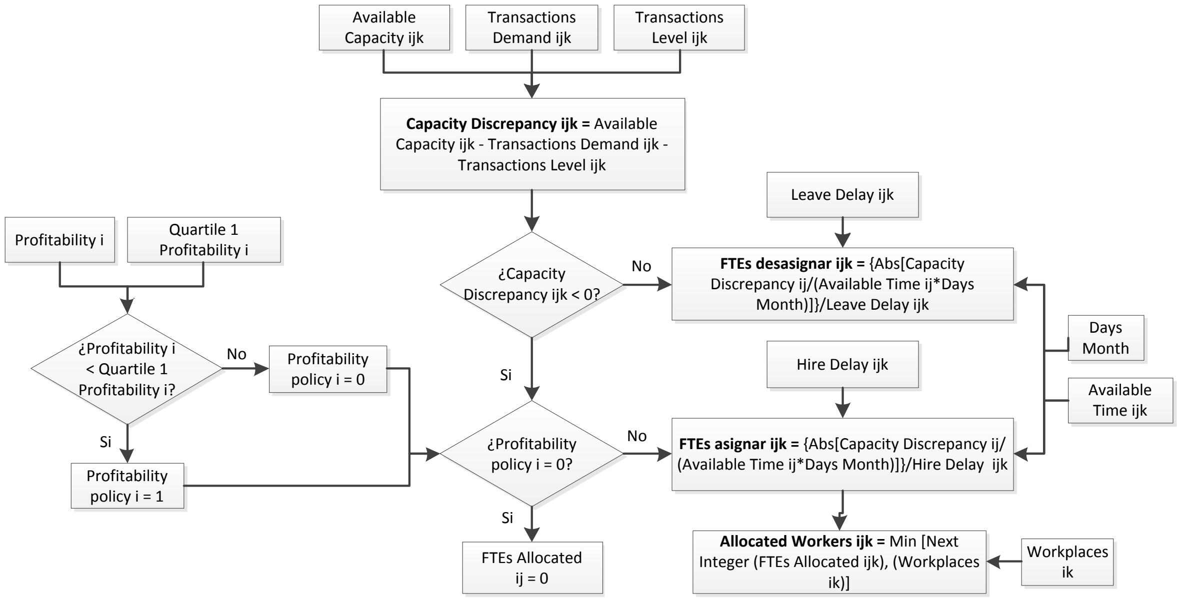


Figure14. *Flowchart of the algorithm for allocating staff*

For the calculation of ATMs installed according to the requirements of the application, is used in the algorithm shown in Figure 15.

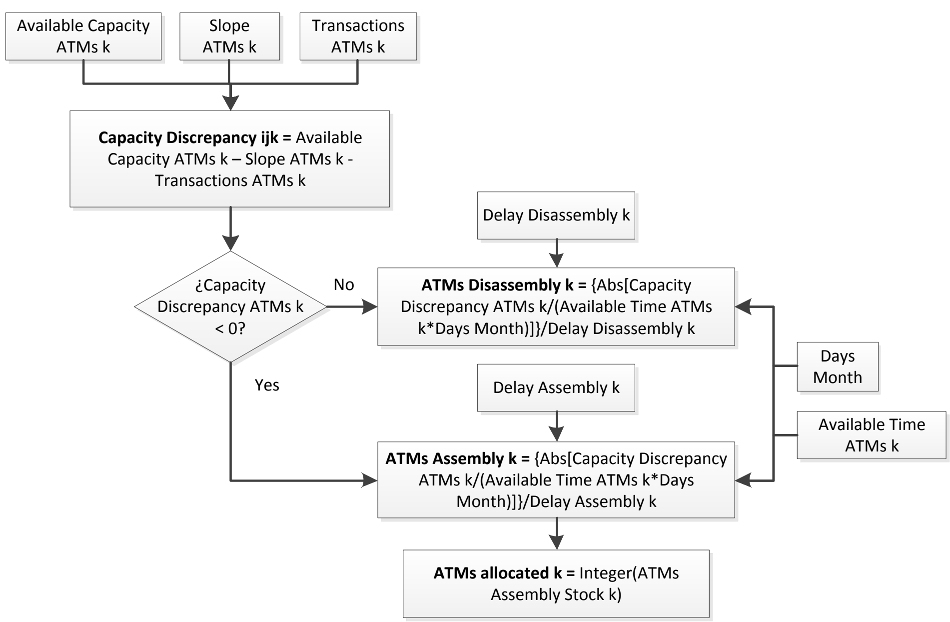


Figure15. *Flowchart of the algorithm for calculating required ATMs*

4.5. Model results

Model results were analyzed through the behavior of workers allocated per shift and process, as well as the allocation of workstations per process and ATMs. As performance measures calculated the average utilization of the available capacity, shortage and idle. This based on two stages: the first one considers the periodic review of capacity requirements (considering specific times to make changes on the number of workers and facilities) and the second one considers continues review of these capacity requirements (with gradual delays in the movement of the system capacity).

4.5.1. Behavior model input data

For information model input, transactions demand in offices was analyzed per process and shift, demand for ATM transactions and profitability per process (see Figure 16).

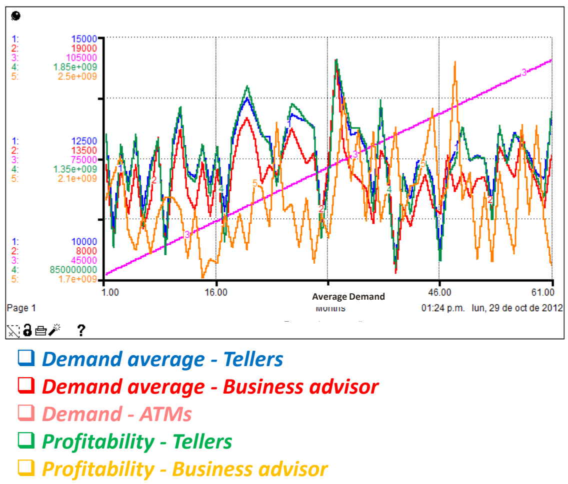
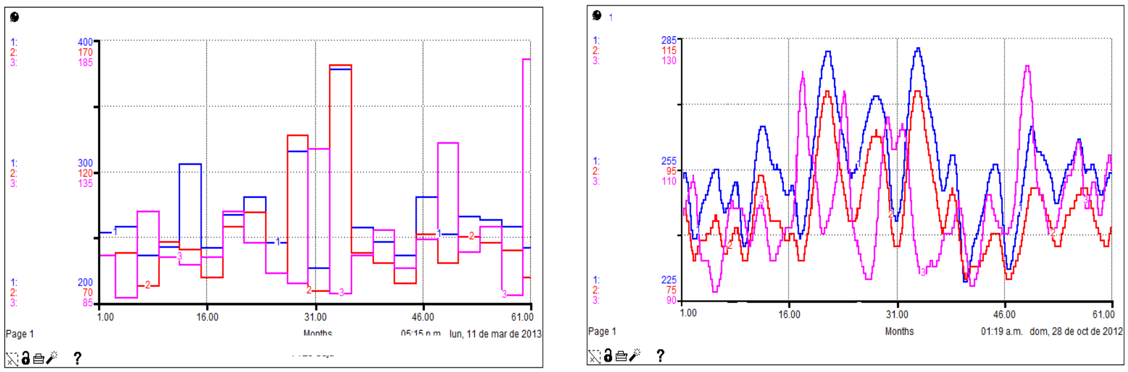


Figure16. *Input data*

4.5.3. Workers per process

The main results of model development found in the workers number allocation per shift and process, for tellers process see Figure 17 per scenario. For business advisors process see Figure 18.

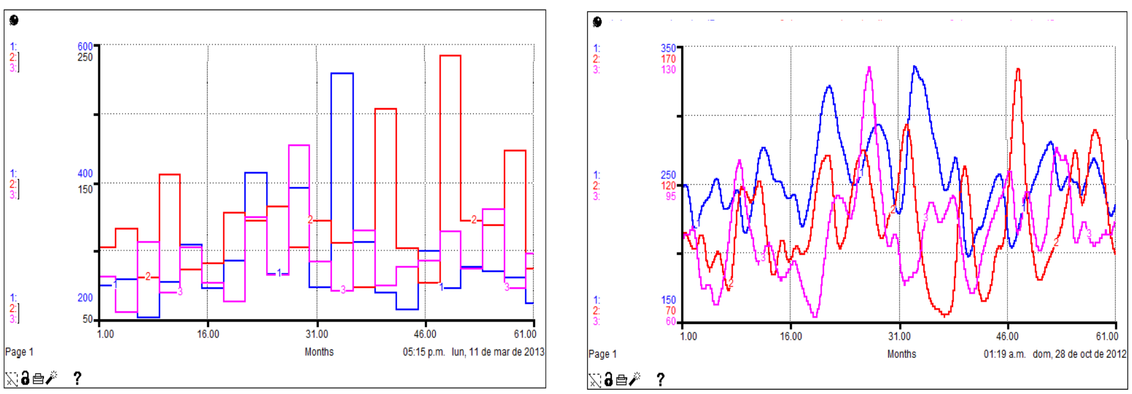
Periodic Review *Continuous Review*



❑ **Tellers - Day shift**
❑ **Tellers - Additional Shift**
❑ **Tellers - Saturday Shift**

Figure17. *Tellers allocation per shift and scenario*

Periodic Review *Continuous Review*



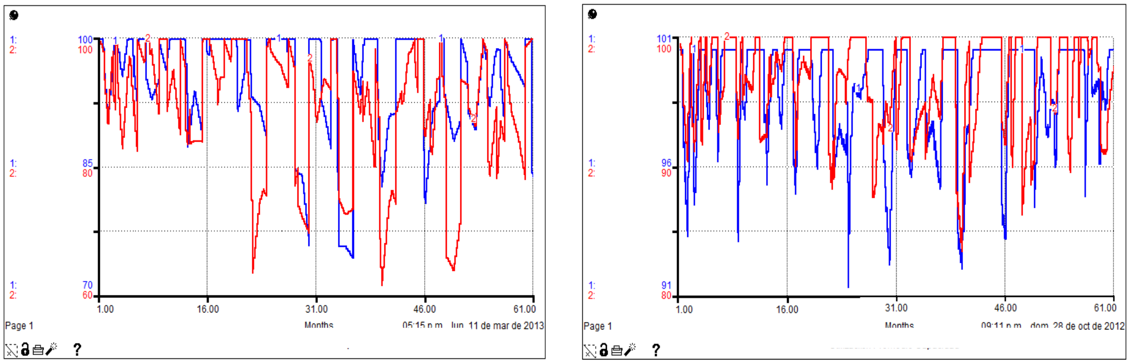
❑ **Business advisors - Day shift**
❑ **Business advisors - Additional shift**
❑ **Business advisors - Saturday shift**

Figure18. *Business advisors allocation per shift and scenario*

4.5.4. Average utilization of the available capacity (workers allocated)

The main objective of the model is to achieve maximum utilization of available capacity through better allocation for workers per process and shift. Analyzing the average utilization hours for process values are about 100%, with better performance on scenario with periodic review (minimum 92%) compared with continuous review scenario (minimum 62%) (see Figure 19).

Periodic Review *Continuous Review*



❑ ***Average Utilization of the available capacity Tellers***

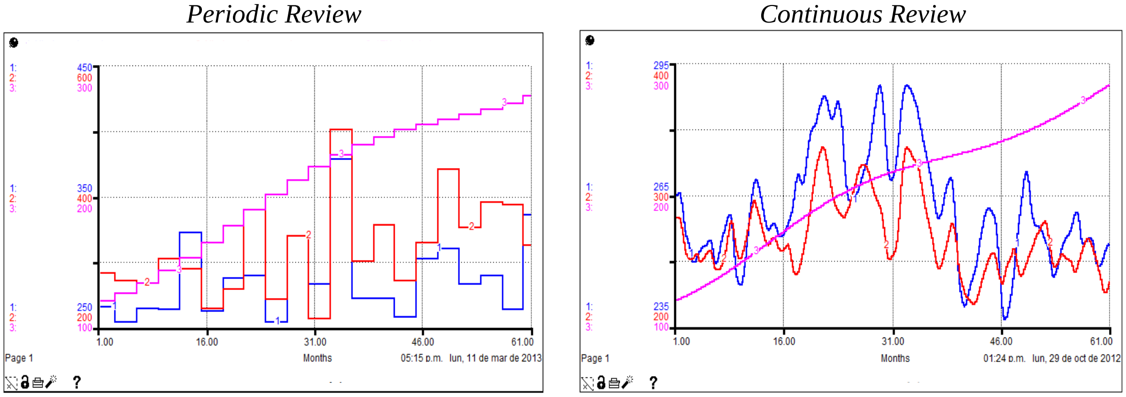
❑ ***Average Utilization of the available capacity Business advisors***

Figure19*. Average utilization of the available capacity per process*

4.5.5. Facilities (ATMs and workstations per process)

From workers allocation the need arises for the creation or elimination of jobs for the service (see Figure 20).

Periodic Review *Continuous Review*



❑ ***Number of workstations - Tellers***

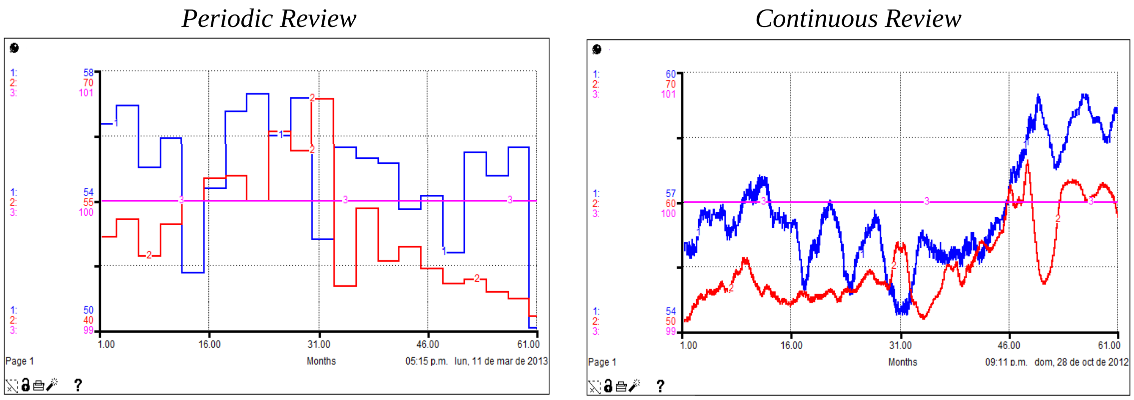
❑ ***Number of workstations - Business advisors***

❑ ***Installed ATMs***

Figure 20*. Facilities (ATMs and workstations per process)*

4.5.6. Available capacity utilization of the facilities

Moreover the use of available capacity ATM is always 100% because the linear behavior identified. The workstations average utilization is affected by the allocation defined, since the model calculates a number of workstations required for all shifts, based on the maximum number of workers allocated per process. Better performance is found in the continuous review scenario (see Figure 21).

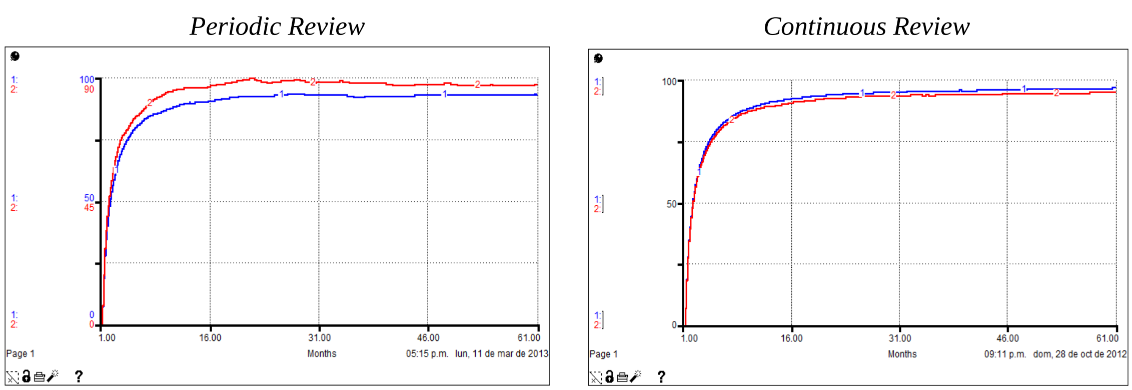


❑ **Average capacity utilization *Tellers***
❑ ***Average capacity utilization Business advisors***
❑ ***Capacity Utilization ATMs***

Figure21*. Available capacity utilization of the facilities (ATMs and workstations per process)*

4.5.7. Convergence of the available capacity utilization (workers)

The cumulative average percentage utilization of the available capacity of workers per process, has the better percentage in the continuous review scenario with a minimum of 95% and for the periodic review scenario with a minimum of 88% (see Figure 22).

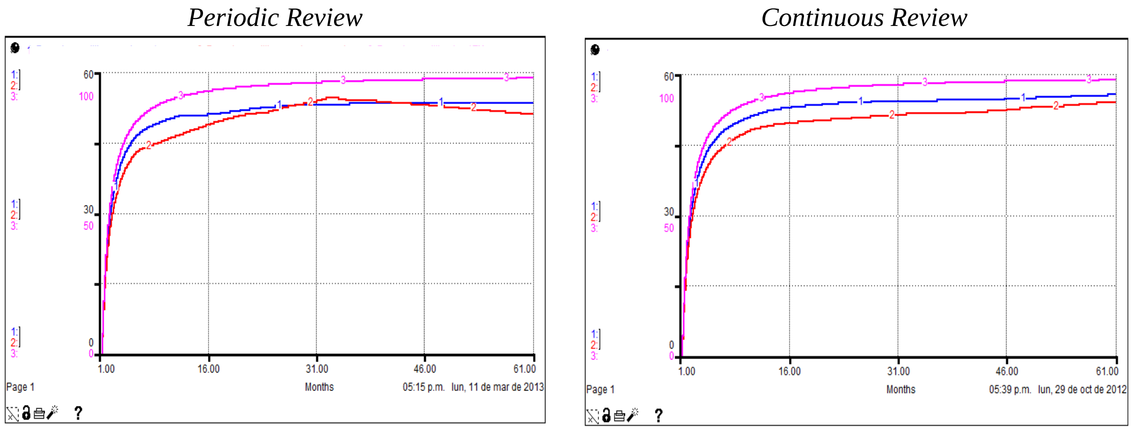


❑ **Average capacity utilization - *Tellers***
❑ ***Average capacity utilization - Business advisors***

Figure 22*. Convergence of the available capacity utilization per process*

4.5.8. Convergence of the available capacity utilization (ATMs)

The cumulative average percentage of available capacity utilization converges for ATMs around 98% for the two scenarios. For tellers workstations is 54% in periodic review scenario and 56% in continuous review scenario. For business advisors workstations is 51% in periodic review scenario and 54% in continuous review scenario (see Figure 23).

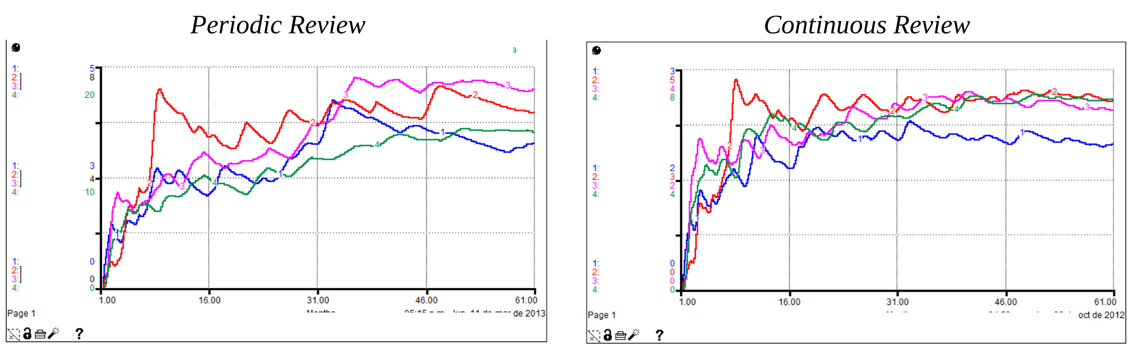


❑ ***Tellers workstations***
❑ ***Business advisors workstations***
❑ ***Average capacity utilization***

Figure 23. *Convergence of the available capacity utilization (ATMs and workstations per process)*

4.5.9. Convergence of shortage and idle capacity (workers allocated)

Noting the average percentage of capacity accumulated (shortage and idle) per process, for tellers process converge about 3% and 7% respectively in the periodic review scenario and about 2% and 3% respectively in the continuous review scenario. In the case of the business advisors process converge about 6% and 14% respectively in the periodic review scenario and about 4% and 7% respectively in the continuous review scenario. This corresponds to the objective of achieving the best use of available capacity. (see Figure 24).



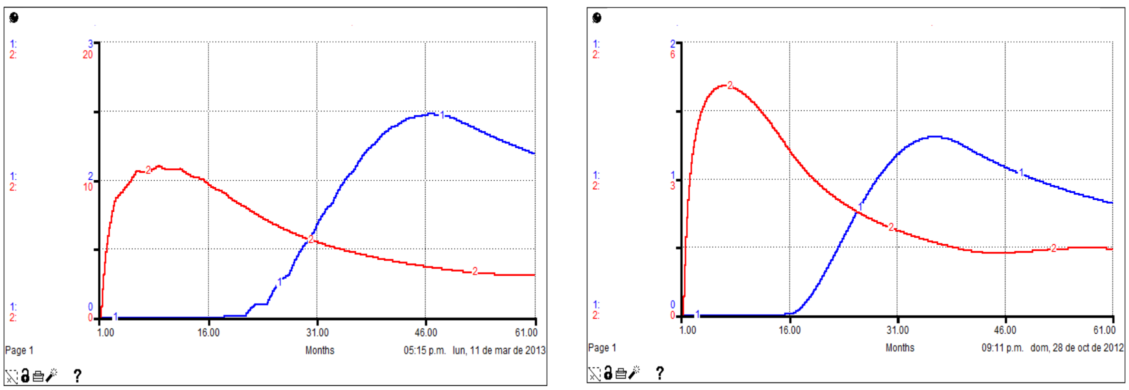
❑***Tellers - Shortage Capacity***
❑***Business advisors - Shortage Capacity***
❑***Tellers - Idle Capacity***
❑***Business advisors – Idle Capacity***

Figure 24. *Convergence of shortage and idle capacity (workers allocated)*

4.5.10. Convergence of shortage and idle capacity (ATMs)

In the case of ATMs, the cumulative percentage of shortage and idle capacity converge about 3% and 2% respectively for the periodic review scenario and about 2% and 1% respectively for the continuous review scenario (see Figure 25), which is consistent with the rate of use (100% during the run of the model).

Periodic Review *Continuous Review*



❑ Accumulated average Idle Capacity ATMs
❑ Accumulated average Shortage Capacity ATMs

Figure25. *Convergence of shortage and idle capacity (ATMs)*

5. CONCLUSIONS

In the last twenty years the service industry has exponentially increased its trade balance in billions of dollars, a situation that is replicated to the service industry in Colombia, especially for financial companies with large share in national GDP and Within this sector, credit institutions have higher earnings to June 2012, also the percentage of people employed in the service industry of the country, are elements constitute a research opportunity in this economic sector.

The models applied to the study of the capabilities of the production systems are based on the manufacturing industry and are applied in analyzing service industry variables that generally range from service demand, to the study of the resources involved, even in models addressing the problem through system dynamics, but not fully considering the components included in this research, specifically analyzing the behavior of workers allocated per processes (tellers and business advisers) and shift (diurnal, additional and Saturday), in contrast to conventional planning models presenting capacity allocation constraints, through system dynamics to analyze the assignment was achieved through feedback loops.

When performing statistical analysis of historical data (24 months) for transactional demand and profitability of the system. Using generators with random variables identified, it was possible to simulate the behavior of a planning horizon longer (60 months), which affected the fluctuating levels of resource allocation generated by the model, considering delays and search for the maximum use of available capacity.

Identifying and calculating abilities involved in the modeling, it was possible to compare the behavior of the model, which means finding the best configuration in resource allocation, aims to maximize the use of available capacity, reducing the other hand percentages of missing capacity and idle capacity. What is of interest to system planning, given the costs associated with the underutilization of the workforce or under-provision of customer service.

Using the model developed in this research were able to observe the behavior of the system as a whole, contributing to the study of their behavior broken down by day, and the requirement process electronic channel ATMs. Under the proposed scheme can detect staffing requirements, job requirements and installation of ATMs, which meet the requirements fluctuating demand for services, the above as support decision making with respect to growth or decline in the resources available studied.

The model is proposed for the analysis of operational capabilities in service companies that include human resources and facilities, where they present a demand for services of various kinds to be attended by skilled personnel in different facilities. The search for the best configuration of the resources involved in the single service, enables companies in this sector continued inquiry about obtaining better utilization rates.

Future work on the model developed, will focus on the study of the effect on employment generation increased electronic transactions, analyzing requirements for new skills of the workforce, the effect on salaries, customer service requirements and facilities for the service. Integration with models is considered, that include investment variables, processes, placement, recruitment, treasury and among.

6. REFERENCES

[1] «Organización Mundial del Comercio (OMC),» [En línea]. Available: http://stat.wto.org/Home/WSDBHome.aspx?Language=E. [Último acceso: 02 Septiembre 2012].

[2] Departamento Administrativo Nacional de Estadistica (DANE), «Encuesta Anual de Servicios (2010),» 22 Mayo 2012. [En línea]. Available: http://www.dane.gov.co/index.php?option=com_content&view=article&id=888&Itemid=28. [Último acceso: 02 Septiembre 2012].

[3] Superintendencia Financiera de Colombia, «Superfinanciera,» Actualidad del Sistema Financiero Colombiano, Junio 2012. [En línea]. Available: http://www.superfinanciera.gov.co/ComunicadosyPublicaciones/comsectorfinanciero062012.pdf. [Último acceso: 2012 Septiembre 05].

[4] Y. Liu, D. Tipper y P. Siripongwutikorn, «Approximating optimal spare capacity allocation by successive survivable routing,» *IEEE/ACM Transactions on Networking*, 2005.

[5] M. Ningfang, C. Giuliano, C. Ludmila y S. Evgenia, «Sizing multi-tier systems with temporal dependence: benchmarks and analytic models,» *Journal of Internet Services and Applications,* 2010.

[6] B. John, L. Bob, M. Gillian y S. Tom, «Modelling Outpatient Capacity for a Diagnosis and Treatment Centre,» *Health Care Management Science,* 2005.

[7] G. Abraham, G. B. Byrnes y C. A. Bain, «Short-term forecasting of emergency inpatient flow,» *IEEE Transactions on Information Technology in Biomedicine,* 2009.

[8] S. Leonie y J. L. Matthew, «An evidence-based health workforce model for primary and community care,» *Implementation Science,* 2011.

[9] M. Iftikhar, T. Singh, B. Landfeldt y M. Caglar, «Multiclass G/M/1 queueing system with self-similar input and non-preemptive priority,» *Computer Communications,* 2008.

[10] J.-. H. Huang, L. -C. Wang y C.-. J. Chang, «Throughput-coverage tradeoff in a scalable wireless mesh network,» *Journal of Parallel and Distributed Computing,* 2008.

[11] S.-. H. Jung, J.-. W. Hong, W. Chang y C.-. H. Lie, «Quality of service estimation for soft handoff region ratio and call admission control in CDMA cellular systems,» *Computers and Industrial Engineering* , 2009.

[12] K. Xiaozhu, Z. Hui, J. Guofei y C. Haifeng, «Understanding Internet Video sharing site workload: A view from data center design,» *Journal of Visual Communication and Image Representation,* 2010.

[13] Y. Jiang y A. Seidmann, «Managing information intensive service facilities: Executive contracts, market information, and capacity planning,» *Proceedings of the Annual Hawaii International Conference on System Sciences,* 2010.

[14] G. Casale, N. Mi y E. Smirni, «Model-driven system capacity planning under workload burstiness,» *IEEE Transactions on Computers,* 2010.

[15] Q. Wang, «Modeling and analysis of high risk patient queues,» *European Journal of Operational Research,* 2004.

[16] R. K. Palvannan y K. L. Teow, «Queueing for Healthcare,» *Journal of Medical Systems,* 2010.

[17] R. S. Segall, «Some quantitative methods for determining capacities and locations of military emergency medical facilities,» *Applied Mathematical Modelling,* 2000.

[18] D. Nico, J. Jully y M. Gergely, «Budget allocation for permanent and contingent capacity under stochastic demand,» *International Journal of Production Economics,* 2011.

[19] Statistics Explained, «Eurostat,» European Commission, [En línea]. Available: http://epp.eurostat.ec.europa.eu/statistics_explained/index.php/Glossary:Full-time_equivalent. [Último acceso: 16 Septiembre 2012].

[20] S. W. White y R. D. Badinelli, «A model for efficiency-based resource integration in services,» *European Journal of Operational Research,* 2012.

[21] E. Fragnière, J. Gondzio y X. Yang, «Operations risk management by optimally planning the qualified workforce capacity,» *European Journal of Operational Research*, 2009.

[22] J. Hwang, L. Gao y W. Jang, «Joint demand and capacity management in a restaurant system,» *European Journal of Operational Research*, 2010.

[23] R. L. Cheu, H. Lei y R. Aldouri, «Optimal assignment of emergency response service units with time-dependent service demand and travel time,» *Journal of Intelligent Transportation Systems: Technology, Planning, and Operations*, 2010.

[24] S. Netessine, G. Dobson y R. Shumsky, «Flexible service capacity optimal investment and the impact of demand correlation,» *INFORMS*, 2000.

[25] N. C. Georgantzas, «Perceptual Dynamics of "good" and "poor" service quality,» de *The 11th International Conference of the System Dynamics Society*, Cancun, 1993.

[26] J. Homer, «Macro- and Micro-Modeling of Field Service Dynamics,» de *The 16th International Conference of the System Dynamics Society*, Québec City, 1998.

[27] P. M. Senge y O. Rogelio, «Developing a Theory of Service Quality/Service Capacity Interaction,» de *The 11th International Conference of the System Dynamics Society*, Cancun, 1993.

[28] A. J. Edward G, «Managing Software Implementers in the Information Services Industry: An Example of the Impact of Market Growth on Knowledge Worker Productivity and Quality,» de *The 16th International Conference of the System Dynamics Society*, Québec City, 1998.

[29] E. G. Anderson, D. Morrice y G. Lundeen, «The physics of capacity and backlog management in service and custom manufacturing supply chains,» *System Dynamics Review*, vol. 21, nº 3, p. 217–247, 2005.

[30] M. Becerra Fernández, O. R. Romero Quiroga, M. M. Herrera Ramírez y J. Trujillo Díaz, «Modelamiento de la demanda de servicios logísticos de almacenamiento a través de dinámica de sistemas,» de *IX Congreso Latinoamericano de Dinámica de Sistemas y II Congreso Brasileño de Dinámica de Sistemas*, Brasilia, 2011.

[31] D. Kalenatic, Modelo Integral y Dinámico para el Análisis, Planeación, Programación y Control de las Capacidades Productivas en Empresas de Manufactura, Bogotá: Instituto de Estudios e Investigaciones Educativas, Universidad Distrital Francisco José de Caldas, 2001.

[32] J. A. Orjuela, I. Huertas y D. Kalenatic, Modelo Integral y Dinámico para la Gestión de Empresas de Servicios, Bogotá: Universidad Católica de Colombia, 2008.