Journal of System Management (JSM)
Online ISSN: 2538-1571
Print ISSN: 2322-2301
Vol. 7, No. 2, (26) 2021, pp. 23-57
Research Paper

Simulating the Maintenance Performance on the Attractiveness of Data Center Services: A System Dynamics Approach

Mohammedreza Bahrami [1] **Gholamreza Hashemzadeh** [2]

Abstract

Nowadays, information-making is growing rapidly due to the developments in technology; thus, it is critical to maintain information and establish integrated systems for storage and office automation in any organization; thereby, the establishment of datacenters has become a requirement for them. Despite offering models related to some parts of the data centers, there are still ambiguities in identifying the influential and key variables. This study aimed at offering a dynamic model for the parts related to the attractiveness of data center services by using Vensim software. Five reinforcing loops and seven balancing loops were extracted through studying the review of literature; then, the relevant stock and flow variables have been defined. Afterwards, the model is presented in the form of cause and effect model and the stock-flow model. Also, various scenarios have been studied, including increasing the training capacity and attractiveness, imposing an overload on the network and switch failure, upgrading the bandwidth carrying capacity, reducing the maximum maintenance. According to the results and sensitivity analysis done in this research, it can be said that the attractiveness of services, the acquired skills, and the maximum feasible maintenance along with the bandwidth carrying capacity, storage, and processing power of the data centers is so vital in determining the performance level of data centers and the attractiveness of services.

Keywords

Maintenance, Repair, Data Centers Network, Services Attractiveness, System Dynamics

Received: 18/05/2021 Accepted: 07/08/2021

[1.2.] Department of Management, South Tehran Branch, Islamic Azad University, Tehran, Iran
Corresponding Author: gh_hashemzadeh@azad.ac.ir

Introduction

Today, organizations need to use IT systems in order to accomplish their missions, which is necessitated the establishment of data centers and it makes possible to provide the current structures, laws, and strategies in the field of IT. This article aimed at developing a system dynamic model and evaluating the impact and performance of maintenance programs conducted on the attractiveness of using services, which are available in a data center; and also identifying the nature of system behavior, then examining the impact of various policies on the attractiveness of using and the number of online users in the data center. In other words, this study seeks to identify the number of online users and the role of services attractiveness, which are affected by user's skills, rules and policies of access, reliability and the level of available services; and these factors are also influenced by the damages and the level of maintenance programs and reliability. Then, it would be possible to take steps towards improving the network performance of data centers and increasing its users by system modeling. Data center refers to a series of elements such as the physical environment, servers, and media for storing information, communication and services, which its proper function will cause stability and also improve the service speed, business continuity, and survival of organizations. Since, the equipment is employed to provide, maintain and support network services (Internet/ Intranet/ Extranet), it is essential to consider the capabilities and services, which are offered by them (NikPey, and Torabi, 2012). It has tried to evaluate each of these sectors tasks and functions, as well. Then, the optimal values of maximum activity in the data center and the compliance rate of their performance were identified by standards such as TIA-942 using system modeling. Despite the mobility of network nodes and the lack of any fixed reinforcing, data center network has been taken into considered and being used. However, data disturbance when strengthening the intermediate nodes and the possibility of misbehaving nodes are limitations of this study that have been hampered it to develop and operate widely (MesbahiFard *et al* ,2007). The System dynamics approach that deals with the application of principles and techniques for feedback control in issues related to the managerial, organizational, industrial, and information technology, now it is used to meet this requirement and to analyze and improve projects' performance for three decades. Multiple applications, new and improved models, and value creation for customers are representative of the success of this method for modeling the dynamics of project (Naiyebi, *et al.,* 2008).

Background

Sectors of data centers modeling, in such an extent, are increasingly complicated and comprised of multiple interdependent components. Considering features such as delays in programs' performance, efforts to detect and correct errors, the high volume of transactions, the need for responding to unforeseen changes, feedback processes and non-linear relationships, and the presence of soft data along with hard data, it would be possible to consider these projects as the complicated dynamic systems. This study continues with reviewing the recent research results on planning, maintenance, other components related to users in data centers; then, it addresses to the simulation of various components affecting the performance of data centers. (Cahyo, *et al*., 2014). in a study entitled "Managing Maintenance Resources for Efficient Asset Utilization" have discussed on the policies for managing maintenance resources based on modeling system dynamics associated with it and they have offered the cause and effect loops in three divisions of maintenance, human resources, and logistics. Then, they have drawn the cumulative flow diagram and have studied the scenarios related to it. The results showed that the first scenario is appropriate for gaining higher inventory and supporting the maintenance activities; and the second scenario is more appropriate when the inventory costs have taken into consideration but the order costs have not. Finally, it is mentioned that the proposed model and the recommended scenarios have caused to increase the product life cycle under the studied condition and select the best scenario for maintenance programs (Cahyo*, et al*., 2014). Mirzaee (2005) in his MA thesis titled "Providing Net Policy using Dynamic System" has tried to provide a tool to assist in management affairs; eventually, he concluded that it is better to have a continuous improvement in the process and technology rather than an immediate and increasing improvement in the level of technology (Mirzaee, 2005). Shah Qoliyan and Yosoufi (2010) in a study entitled "Designing a Model for Evaluating the Efficiency of Electronic Banking Using System Dynamics" have claimed that the improvement of productivity will urge labor to think better, be innovative, investment be targeted, and also production be increased with an optimum quality (Shah Qoliyan, *et al*, 2010). Mccalun (1990) have studied the amount of communication bandwidth required for office automation systems; and they have obtained the highest number of transactions and bandwidth by gathering all the information on peak working hours. Finally, they have identified the minimum amount of needed bandwidth and the type of equipment required for data center network by aggregating all the numbers (Mccallun, *et al*,1990). Beyeler et al (2005) in their paper titled "Inter Infrastructure Modeling Ports and Telecommunications" have stated the modeling and simulation of cross-interactions between infrastructures and scenarios of disruption impacts and the critical infrastructures need to support of other industries to do their business. For example, they estimate the shipments, which have been delayed because of this difficulty (bug), based on the average value per shipment 80000$, contractual lose costs and extra labor costs that was used during network disturbances, a 1.4-million-dollar loss for the disconnection during the specified time; and they concluded that costs of such disturbances for other critical infrastructures will certainly be much higher that the calculated numbers (Beyeler, et al, 2005). LeClaire and O'Reilly (2005) have conducted a paper entitled "Leveraging a High Fidelity Switched Network Model to Inform System Dynamics Model of the

Telecommunications Infrastructure “referring to the national strategy "The Physical Protection of Critical Infrastructures and Key Assets", which has been published by the White House at February in 2003. They have stated that the Critical Infrastructure Protection Decision Support System (CIP/DSS) is designed to provide insights for the Department of Homeland Security in making decisions about investments related to critical infrastructure protection. They have presented summary of the results of collaboration and effort with Bell Laboratories, Lucent Technologies to leverage a switched network simulation in the telecommunications system dynamics model. They have found that the availability and communications drop to 5% at peak calling times in the event of disruption or traffic overload on the system; and they have also found that applying a 4 X call overload reduces demands on the night of switches capacities recovery; also reducing the call overload occurs in the first few days (8 days) (LeClaire, and O'Reilly,2005). Awodee and Akanni (2012) in their study entitled “Estimation of Required Bandwidth for Organizations" has mentioned that organizations and individuals have suffered substantially in the hands of the Internet service providers because of their inability to estimate their needed bandwidth over the years. Cisco Net and Brad have offered a solution to adjust TCP window size and the round trip latency so that the desired bandwidth can be obtained. This paper has tried to specify the main factors in the quality and responsiveness of activities that their absence will annoy the network users. Then, they have attempted to identify the affective and distinctive factors of services with important factors in various speeds. They concluded that bandwidth rate and delay are two key factors in the performance of networks; and at the end, delay affects the user. Then, they recommend that organizations apply the rules of "Quality of Service" to prioritize displaced information within their network; so that they can have a better management of the consumed bandwidth and the rate of delay in the networks (Awodee, and Akanni, 2012). Liao et al (2015) in a paper entitled "Understanding the dynamics between organizational IT investment strategy and market performance: A system dynamics approach" have found that there is severe competition among firms in the IT field and IT has become a way to increase organizational performance and get a competitive advantage for organizations. While comparing different scenarios for investment, they found that it is more appropriate to choose a long-term strategy for investment in the IT field and this investment is essential to maintain the competitive performance in the market (Liao, *et al*,2015). Genge (2015) in a paper entitled "A System Dynamics Approach for Assessing the Impact of Cyber Attacks on Critical Infrastructures "have stated that the massive proliferation of information and communication technologies have caused to apply into the heart of modern critical infrastructures and infrastructure systems be exposed to the cyber-attacks and threats related to it. They have proposed a new methodology for assessing the effects of cyber-attacks on critical infrastructures, which is inspired by system dynamics ad sensitivity analysis of variables. Then, they have simulated it in the power grid and analyzed the precision of anomaly caused by the cyber-attacks (Genge, *et al*, 2015). Considering system dynamics models in the field of IT security, Nazareth and Choi (2014) in a paper entitled "A system dynamics model for information security management "have claimed that managing security for information assets of an organization is so important and the dynamic model proposed by them is well explained the importance of investing in the context of security and risk assessment; so that, they have indicated that if expensive security tools be purchased; then, costs of damages caused by attacks will reduce up to 32000$ as well as the invested costs for security will be reduced up to 153000$; and it has done in order to an appropriate initial investment for managing security and purchasing equipment associated with it. They believe that the proposed model can be used for assessing the various security policies of competitors or as a decision support system (Nazareth and Choi, 2015).

Method

This study has simulated a comprehensive model consisting of all factors affecting a data center by using Vensim software. It provides Causal Tracing of structure and behavior, and has Monte Carlo sensitivity, optimization and subscripting (array) capabilities (Cahyo, *et al.* 2012). This research is simulated during four-time steps that the length of time period for each was one year. For identifying the characteristics of data centers and factors affecting the maintenance programs and attractiveness of services, causal loops were formed according to the observations on the behavior of the system by using system dynamics methodology; and also, they were inspired by the valid theories in the field of this study's literature; then, the dynamic hypothesis associated to each of them were presented; in total, five reinforcing loops and seven balancing loops were identified. The positive relationships were marked with arrows along with "+" sign and the negative relationships were marked with "-" sign. Meaning that in the positive causal relationship, assuming that all other variables remain constant, a change in one variable affects other variables in the same direction; and in the negative causal relationship, a change in one variable affects other variables in the opposite direction. Also, if in a loop the number of negative links (-) in a feedback loop is zero or even, the polarity of the loop is positive ; and if it is odd, the polarity of the loop is negative − (Sterman , 2013). In the subsystem R1 that is considered as one of the reinforcing loops of this system, is mentioned for the reinforcing role of attractiveness in using service in investment and the purchase of equipment. In this subsystem, the pressures for enhancing investment in infrastructure will also rise by increasing the attractiveness of using service during a unit of time; this will increase investment in infrastructures; following increasing the investment, purchasing and upgrading the equipment will also increase and it will enhance the total number of available communications equipment. Considering the desired and necessary level of equipment, increasing the total number of equipment will reduce the difference in rate between the required equipment and the total number of available equipment; and the attractiveness of using services will increase by reducing the difference between the required equipment. The second reinforcing subsystem of a model called R2, which refers to the relationship between the increasing number of users and attractiveness of services, indicates that whatever the attractiveness of using services available in data center networks increases, the number of users, who are using service, will also increase; and thus, the increasing will enhance the attractiveness, as well.

Figure 1.
R1 Loop Reinforcing the Attractiveness of Use and Investment in Infrastructure

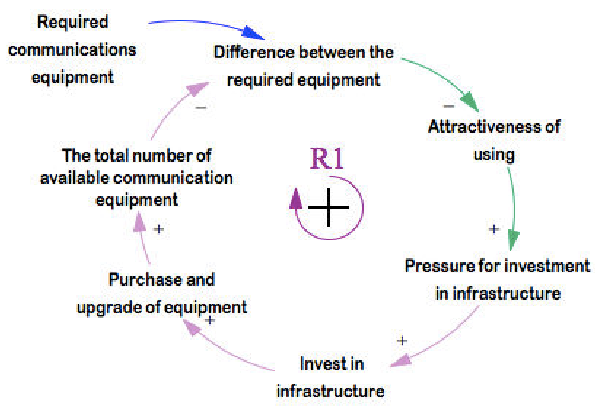
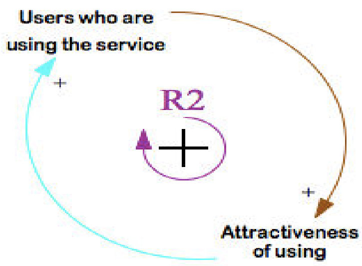
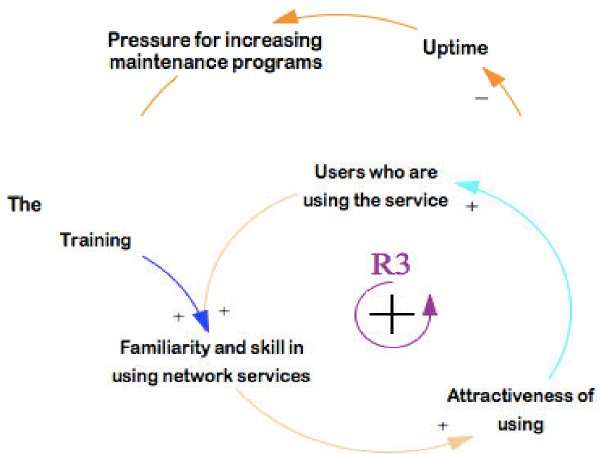


Figure 2.
Loop R2 Reinforcing the Attractiveness of Use and Service Users



In the subsystem R3 that is the reinforcing loop in attractiveness of using and the level of users' familiarity and skill, increase in the familiarity and skill will lead to increase in the attractiveness; and this enhancement will increase the users, who using the service; ultimately, the level of familiarity and skill will increase again. Also, in subsystem R5 that is the reinforcing loop of the relationship between incomplete maintenance and the amount of planned maintenance, whatever the pressure for enhancing the program maintenance increases the amount of planned maintenance will also increase; and it will cause to increase in the level of incompleteness maintenances; then, it will lead to increase in the possibility of damage and equipment failure. Due to the increase in damages, uptime will decrease with this increase; and eventually, it led to the increasing the maintenance programs.

Figure 3.
Loop R3 Reinforcing the Attractiveness of Use and Familiarity and Skill in Services
Figure 4.



Loop R5 Reinforcing the Uptime and Incomplete Maintenances. In loop B2 that is balancing the number of users and the amount of information storage, the amount of data storage over time will enhance by increasing the number of service users. Due to the constraints on the carrying capacity, the remaining capacity has reduced that lead to increasing errors, delayed data, and increasing the service outage; and finally it decreases the number of users who are using the service. Loop B1 also balances the users' number and the consumed bandwidth; after the number of users increased, the consumed bandwidth service over time will also increase; and the remaining capacity decreases due to the constraint on the carrying capacity, which it will lead to increase in error rate and service failure; and ultimately, the number of users, who are using the service, will decrease.

Figure 5: Loop B1 Balancing the Consumed Bandwidth and Users

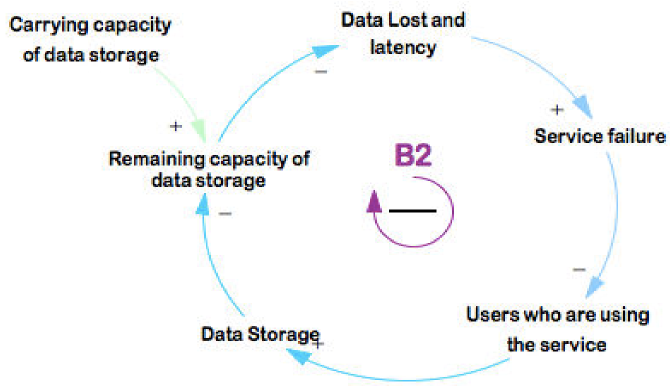
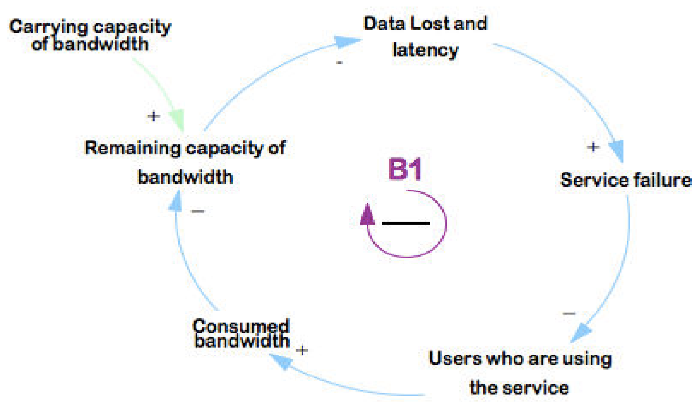


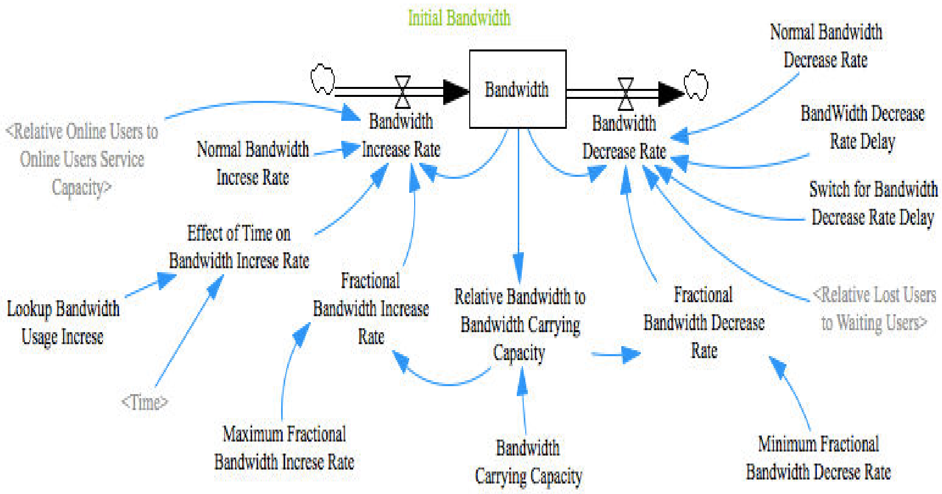
Figure 6: Loop B2 Balancing the Information Storage and Users



Although, CLD can describe the basic structure of the relationships and feedbacks, it cannot display the differences between the variables. In order to show these differences, this study has drawn flow diagrams to separate the stock and flow variables, as well as numeric constants in the system. In the modeling undertaken for data centers, over 125 influential variables and associated with 15 state variables were extracted through studying the literature that its main subsystems will be discussed in the following:

Figure 7.

Formulated Dynamic Model for Stock Variable of Bandwidth

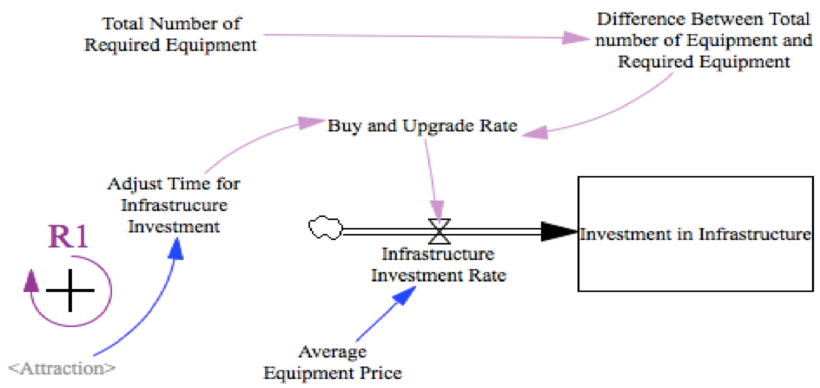


The stock variable of the bandwidth, which is shown in the table 7, is one of the major factors affecting the level of network performance, users and other various factors in the data centers networks. In this subsystem, factors such as the annual growth of bandwidth, the impact of time on the growth rate of bandwidth, and the relative growth rate of bandwidth, which are affected by the carrying capacity of bandwidth, have increased the value of stock variable. And variables like average reduction rate of bandwidth, delay at the reduction rate of bandwidth, the ratio of lost users to the users, who waiting for receiving service, and the relative reduction rate of bandwidth will decrease the value of stock variable through reduction rate of bandwidth. The equation and measurement unit for stock variable of bandwidth are as follows:

Bandwidth = INTEG (Initial bandwidth, the reduction rate of bandwidth, the growth rate of bandwidth)

As it can be seen in figure 8, subsystem of the level of investment in infrastructure is affected the flow variable of investment rate in infrastructure through purchase and upgrade rate and equipment's average price. By this, the state variable of investment in infrastructure will increase annually.

Figure 8.
Formulated Dynamic Model for Stock Variable of Investment in Infrastructure

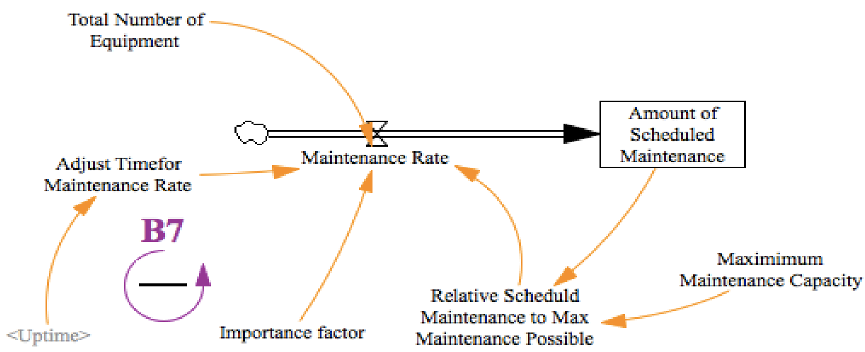


Also, the equation and measurement unit for stock variable of investment in infrastructure are as follows:

Investment in Infrastructure = INTEG (rate of investment in infrastructure, 0)

Figure 9 includes the relationships between the PMS, in which the total number of equipment, correction time of maintenance rate, credibility coefficient, the ratio of planned maintenance to the maximum number of feasible maintenance -influenced by the level of planned maintenance- affect the state variable of the level of planned maintenance through the flow variable of exchange rate of maintenance.

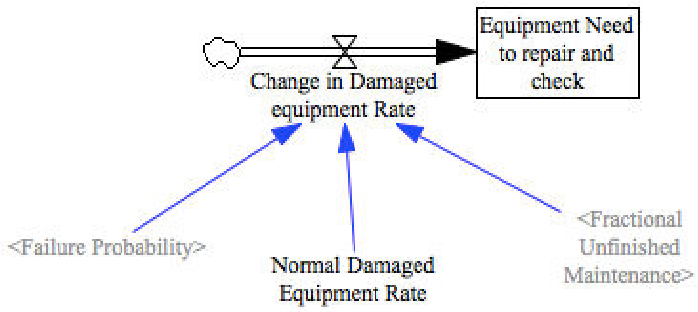
Figure 9.
Formulated Dynamic Model for Stock Variable of PM



Also, the equation and measurement unit for stock variable of PM level are as the following:
PM level = INTEG (change rate of maintenance, 245)

The subsystem of the equipment required handling and repairing is given in the following figure. This subsystem affects the flow variable of equipment failure's change rate through the average annual rate of equipment failure, the possibility of failure, and the incomplete relative maintenance; thereby they affect the stock variable of the equipment required handling and repairing.

Figure 10.
Formulated Dynamic Model for Stock Variable of the Equipment Required Handling and Repairing



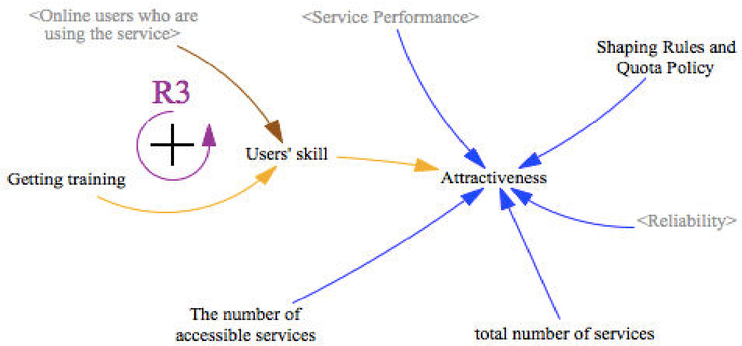
Also, the equation and measurement unit for stock variable of equipment required handling and repairing are as follows:

Equipment required handling and repairing – INTEG (equipment failure's change rate, 0)

As it can be seen in the following figure, the variables of reliability and users' skill –influenced by users who are using service and getting training- affect the variable of attractiveness through rules and policies of access and use restrictions, the number of accessible services, the total number of services, and service capabilities; and it will affect its level over time and according to the written formula.

Figure 11.

Formulated Dynamic Model for Auxiliary Variable of Attractiveness11

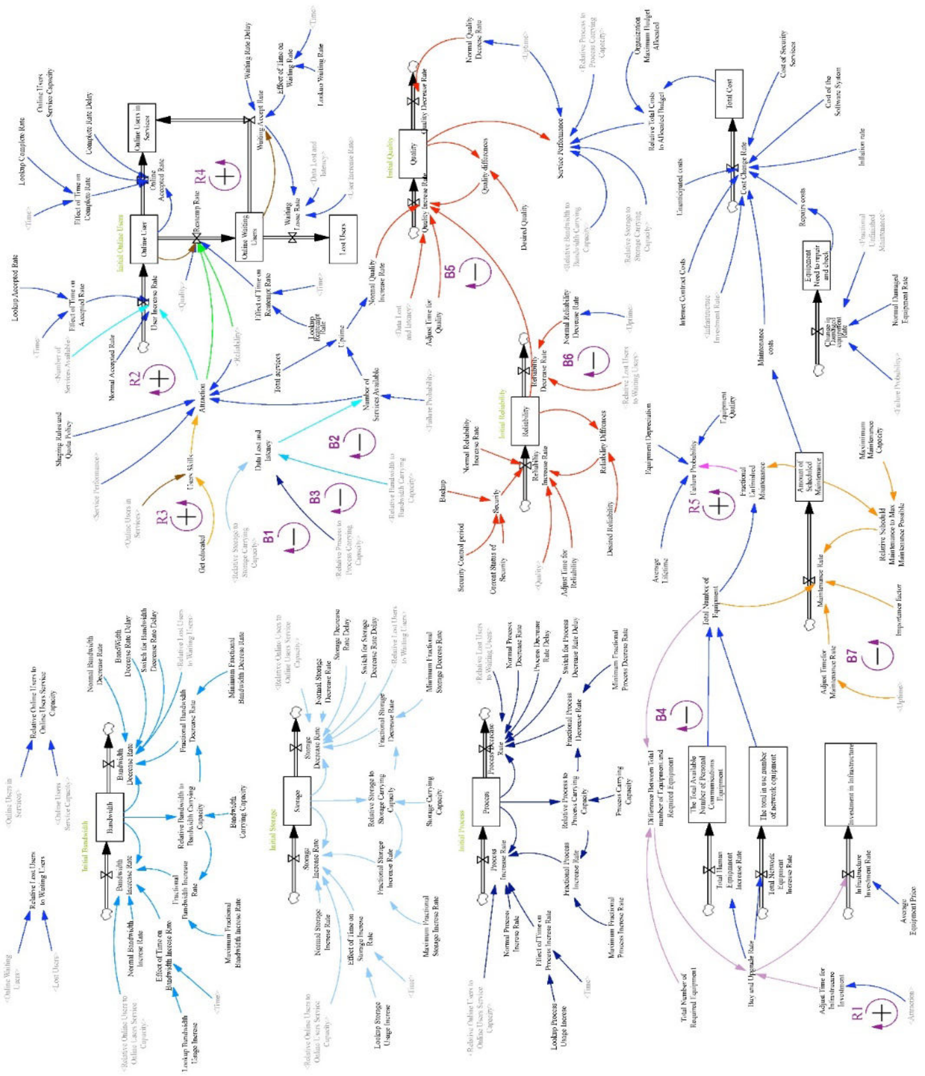


Also, the equation and measurement unit for the auxiliary variable of attractiveness are given in the following:

Attractiveness: (the number of accessible services/the total number of services) * ((reliability + rules and policies of access and use restrictions + users' skill + (service performance / 100)) /4)

Finally, considering all the stock and flow variables as well as the constant and auxiliary variables, figure 12 is presented as the final model for the flow-stock diagram.

Figure 12.
Stock-Flow Comprehensive Model



At first, the presented stock variables were extracted by using the literature related to the modeling data center networks; then, they were completed by studying the domestic literature; and flow, auxiliary, and constant variables affecting them were added to each category. The substantial stock variables that are identified in the model, including bandwidth, storage, processing, online users, waiting online users, online users, who are using the service, lost users, quality, reliability, the total number of human resources' communications equipment, the total amount of equipment used at the network layer, investment in infrastructure, level of planned maintenance, equipment required handling and repairing, and the total cost.

Findings

Dimensional Consistency Test: “Do the dimensions of variables in all equations are in a balanced state on both sides of the equation?" Model health is confirmed by using the option available in the software to do the test.

Boundary Adequacy Test: “Do the important concepts and variables related to the topic placed within the boundaries of the model and are endogenous compared to the model?" With regard to studying and applying models used throughout the world and the international conferences on system dynamics during the past ten years, and using experts' opinions to identify the effect of variables in the model boundary and comprehensive use of data obtained in models as the Lookup functions, it can be said that boundary adequacy test was examined completely.

Parameter Verification Test: After studying the literature and the reference models; then comparing the reference model with the dynamic model presented by statistical dimension, it can be said that there was no contradiction in the formulation of the model from this dimension. Eventually, management experts and professionals of information technology were used to confirm the dynamic model success. According to them, the parameters of the model were confirmed.

Behavior Anomaly Test and Extreme Conditions Test: In behavior anomaly test, unusual changes in variable of waiting online users have been evaluated by eliminating the effect of variables of attractiveness, quality, and reliability. Also, in extreme condition test, this question is answered that "Are all the equations of model significant when are subject to extreme, but possible values of variables?"

Figure 1.
Anomaly Behavior of Waiting Online Users

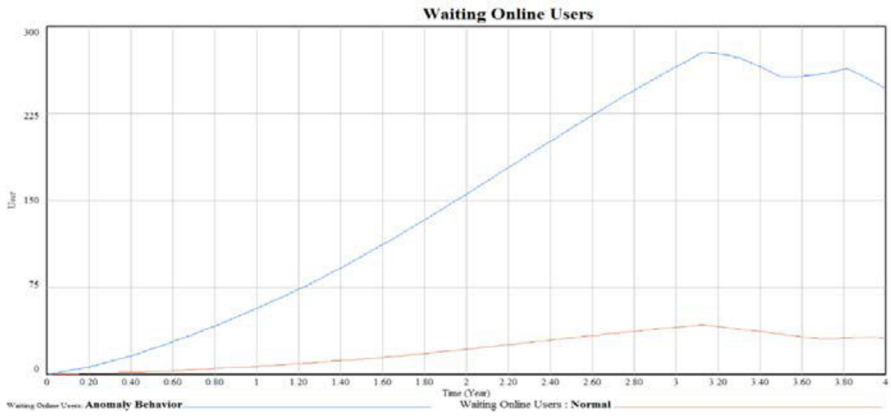
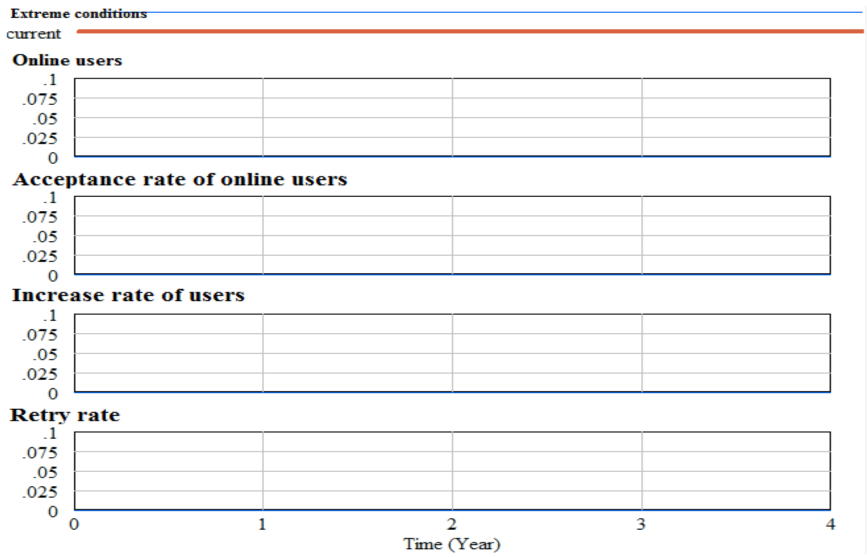


Figure 2.
Users' Significant Behavior in Extreme Conditions



As it can be seen in the figure 13, if the mentioned variables be eliminated, variable of online users, who waiting for using service will show an anomalous behavior in contrast to its previous behavior. According to the figure 14, the acceptance rate status of other relevant variables such as online users using services or users waiting for service also showed a behavior similar to the online users' behavior, which led to a similar behavior in stock variables related to them, as well. So, it can be said that the model was successful in behavior anomaly and extreme conditions tests.

Sensitivity analysis of bandwidth variable: the annual average growth rate is considered as one of the variables affecting the amount of consumed bandwidth in a data center.

Figure 3.

Sensitivity Analysis of Bandwidth Variable

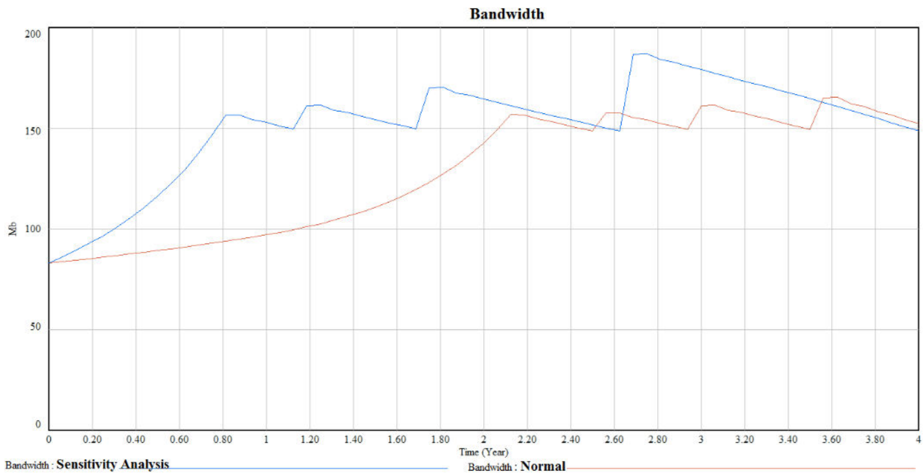
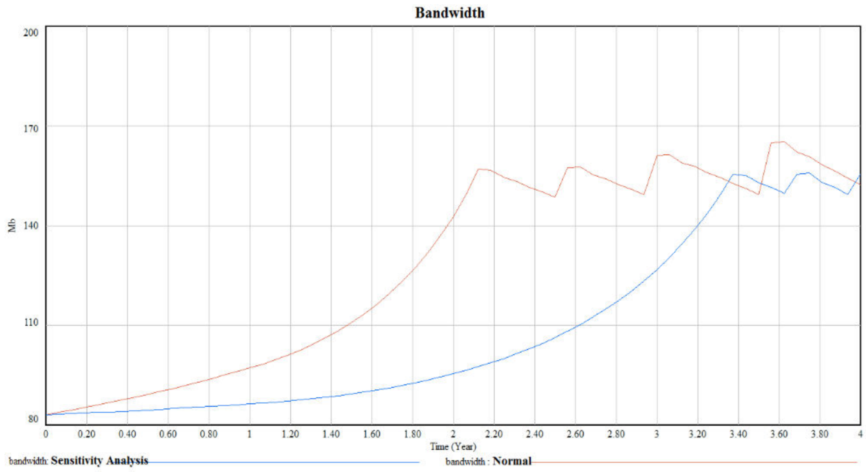


Figure 4.
Sensitivity Analysis of Bandwidth Variable



If the annual growth rate reaches 10%; then, a behavior like figure 16 emerges that its growth rate is very low and experiences a dramatic decline. On the other hand, if the average annual growth rate increases to 90%; then, a substantial growth can be seen in the amount of bandwidth consumption, which is shown in the figure 15.

Regarding the presented dynamic model and the formulation that was mentioned in this chapter, variable of online users related to the factor of service attractiveness. First, the level of service attractiveness is decreased up to 40% for assessing the behavior and sensitivity analysis of it. As it can be seen in figure 17, variable of online users was highly sensitive to the level of attractiveness and on average as much as 30% reduction will be observed in the number of online users. Now, the level of attractiveness increases up to 30% and the following behavior is observed, in which on average up to 20% was added to the number of online users in the data center. As it can be seen in the figure 18, the variable of online users was also highly sensitive to the level of attractiveness and on average as much as 35% reduction will be observed in the number of online users. Now, the level of attractiveness increases up to 30% and the following behavior is observed, in which the number of online users in the data center increases up to 20% on average.

Figure 5.
Sensitivity Analysis of Online Users Variable

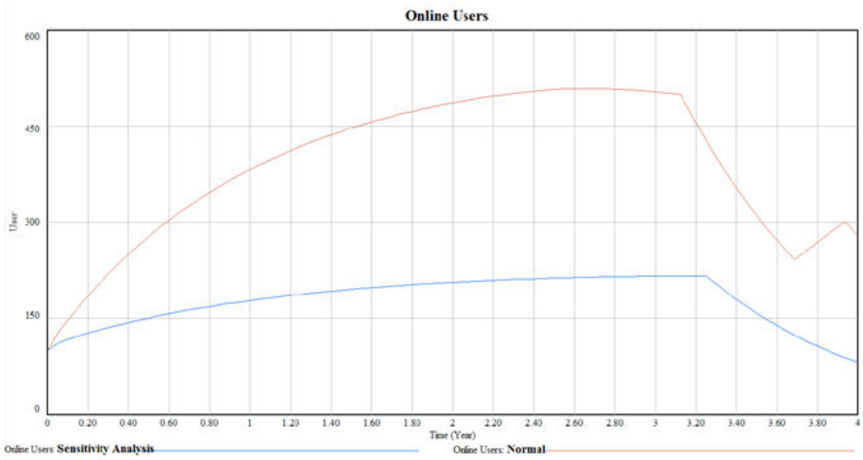
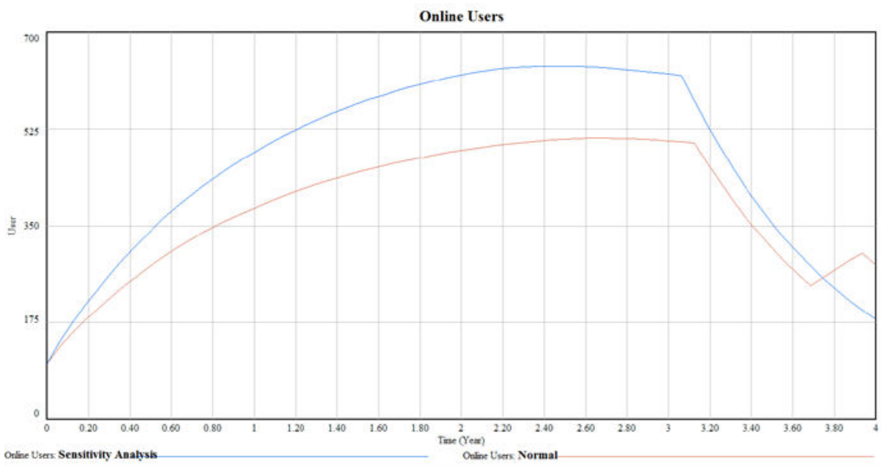
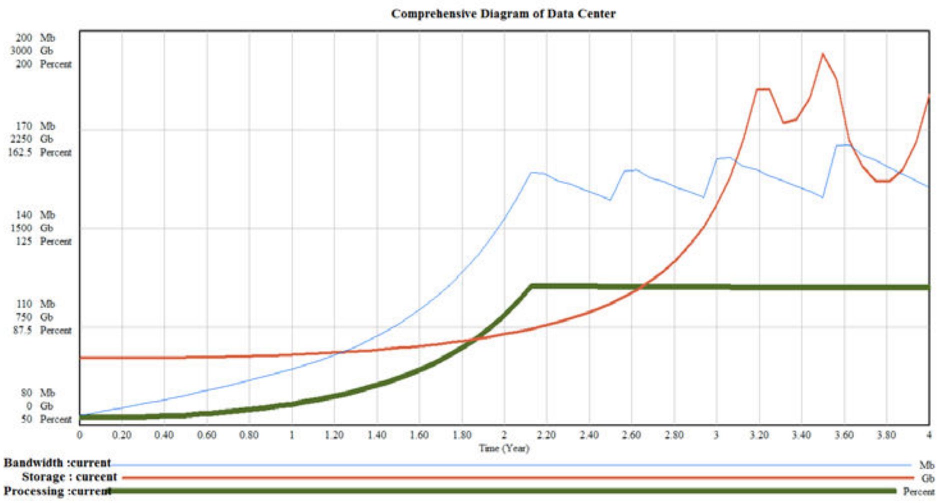


Figure 6.
Sensitivity Analysis of Online Users Variable



This section offers various scenarios for improving the performance of data center capabilities that the results of these scenarios can be analyzed and studied. For designing the scenarios, first, the leverage points of the issue were identified; then, the following scenarios are presented with regard to the recommendations on the policies for increasing the use of electronic services as well as variables in the causal model. In this case, these are no specific policy to conduct on the model and it is applied with the same basic presuppositions.

Figure 7.
Continuing the Status quo Scenario- the Comprehensive Diagram of Data Center



The above figure shows the behavior of bandwidth, storage, the stock variable of processing. As it can be seen in the above model, if the status quo continues with the same process that currently prevails in the data center; then, actual use of the system in the next four years, initially will continue with growth; but, reaching the limitations of carrying capacity will discomfit variables of bandwidth and processing from the second year; and then, variable of storage from the third year and it will follow with oscillatory behavior. In the following, it is discussed whether applying various policies will increase the actual use and performance or not. According to the proposed model and its influencing factors and variables, variable of training capacity is considered as one of the major variables in determining the skills of individuals who can work in the data center network and use services, and this research has tested the trained people during the interval. In this vein, the attractiveness of services is increased and more online users are provided to use the services (Figure 20). As it can be seen, the level of increasing online users with regard to increasing the training capacity from 800 to 2000 people, and enhancing the attractiveness and skill are given in the figure 21.

Figure 8.
Scenario 2: Increasing Capacity of Training and Attractiveness – Users, who are using the services

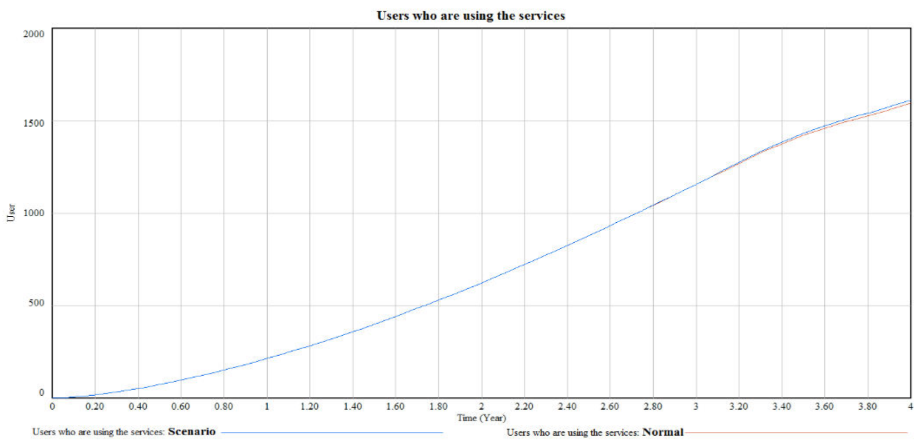
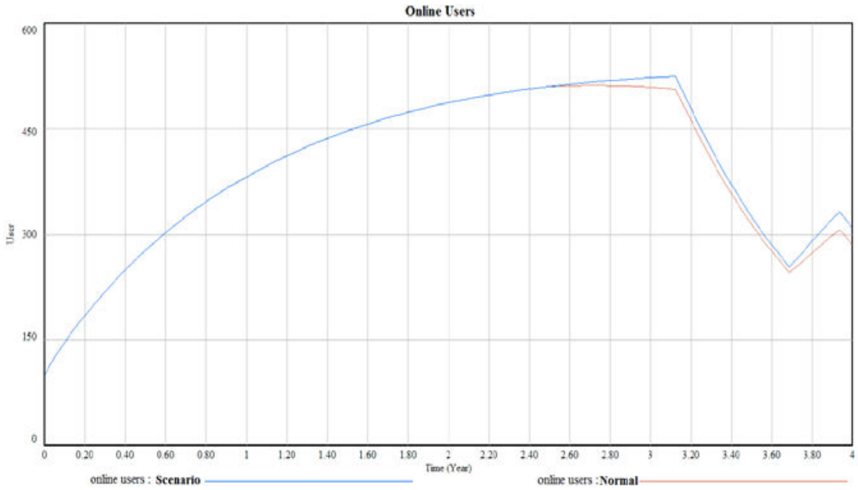


Figure 9.

Scenario 2: Increasing Capacity of Training and Attractiveness – Online Users



Also, the number of waiting online users (figure 23) has increased with regard to increasing the attractiveness of using services, which is influenced by the skills obtained through a higher number of trained people.

Figure 10.

Scenario 2: Increasing the Capacity of Training and Attractiveness – Lost Users

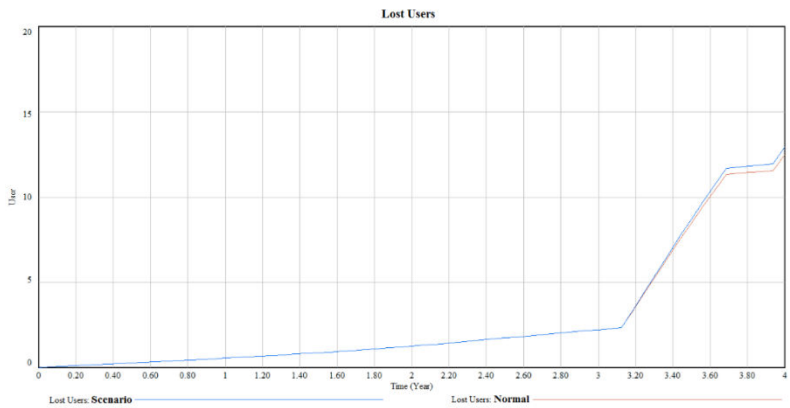
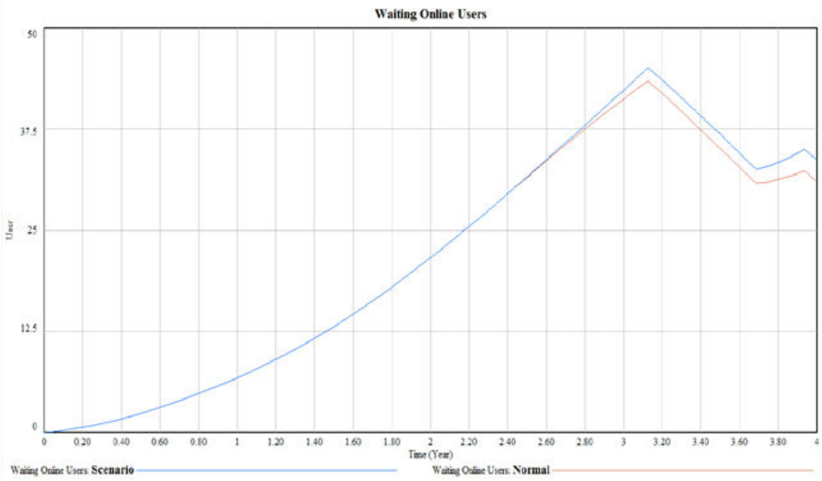


Figure 11.
Scenario 2: Increasing the Capacity of Training and Attractiveness – Waiting Online Users



As it can be seen in figure 22, lost users, who are pushed out of the system through errors and failures, will also increase due to the growing population of users who are logged in the system. As it noted in the above diagrams, in general, increasing the training capacity and training a higher number of service users during model's runtime will increase a great number of users' skill and consequently increase the attractiveness of services. Although, the increase number of users in the system is appropriate, it should be noted that increasing training capacity in the system and enhancing its attractiveness cannot avoid the technical problems and restrictions on the carrying capacity. Thus, those problems have maintained their negative impact on the number of users and the attractiveness of services and the fundamental oscillations and behaviors of users' numbers will be preserved. Imposing an overload on the equipment or failure of any major equipment is one of the most important events and problems occurred in the data center network. This scenario evaluates that if one of the switches, which is related to the infrastructure provides bandwidth carrying capacity, encounters with an overload or fails for 2 months and whereby it would not be possible to upgrade to higher levels of bandwidth; then, what is the impact of them on the online users of services?

Figure 12.
Scenario 3: Imposing an Overload on the Network and Switch Failure – Users, Who Are Using Service

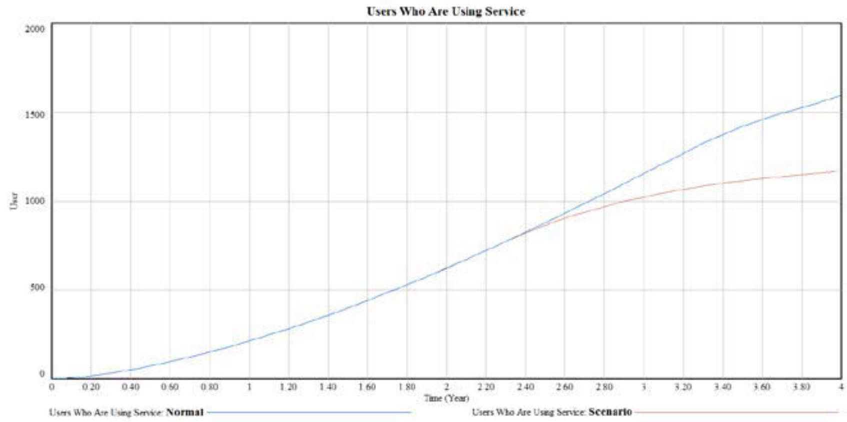
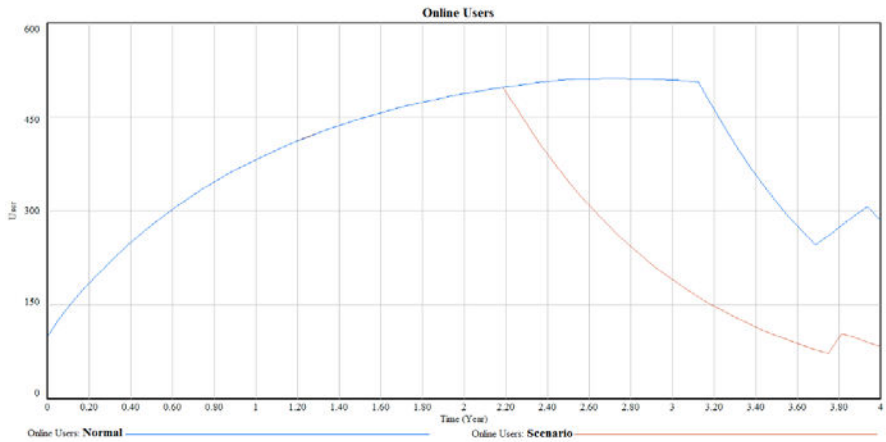


Figure 13.
Scenario 3: Imposing an Overload on the Network and Switch Failure – Online Users



As noted, due to the loss of bandwidth capacity, it faced with slow growth and upgrade and, thereby, fewer users will be attracted during 4 years of using the service. Unfortunately, due to the problem posed in the scenario and attracting fewer online users, obviously, according to the figure related to the online users, who are using service, fewer users were using the service during the simulation interval. This scenario investigates that if the carrying capacity of bandwidth in the data center network be upgraded from its current value (150 MB) to the double value of its capacity, what kind of impact it will have on the final users of services? The following figure shows the change in online users. As it can be seen in the figure 26, due to the less restrictions on bandwidth and availability of services, the number of online users increases and compared to its initial state has improved during the third years. Also, as it can be seen in the figure 27, the number of the final users of services is improved in order to apply the mentioned policy and they will experience a greater number that the previous conditions.

Figure 14.
Scenario 4: Improving the Carrying Capacity of Bandwidth in the Data Center – Online Users

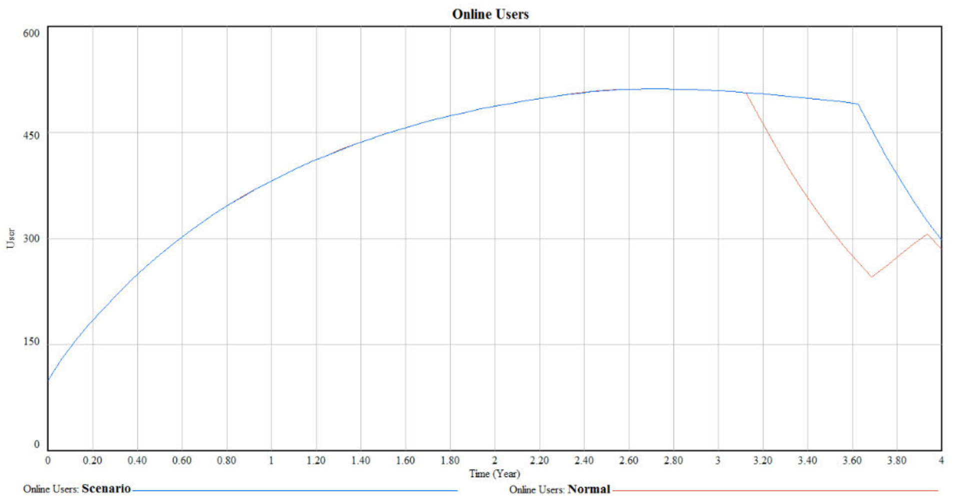
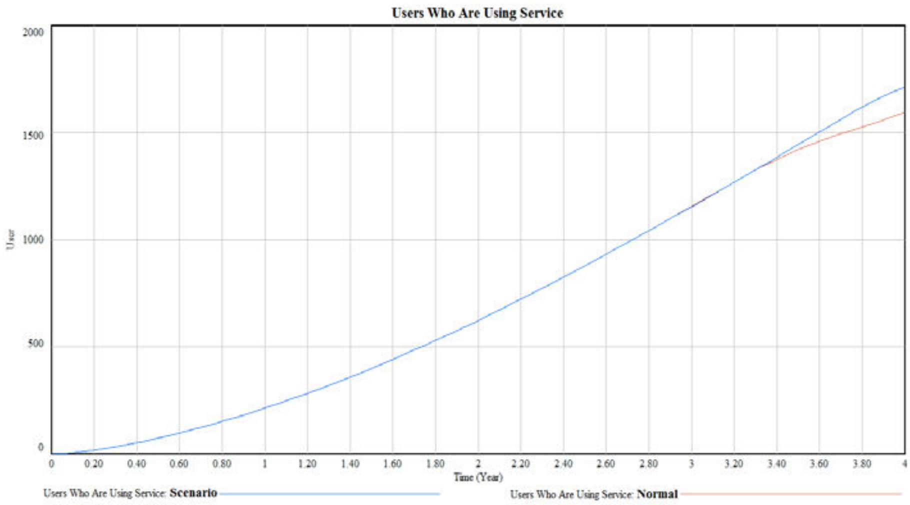


Figure 15.
Scenario 4: Improving the Carrying Capacity of Bandwidth in the Data Center – Users, Who Are Using Service



According to the applied policy, which is shown in figure 28, the number of waiting online users also increased and it caused more attractiveness of services, which itself led to a greater willingness to use services even when it is busy. Also, changes in lost users regarding the applied policy and promoting carrying capacity of bandwidth have decreased the number of lost users, which is shown in figure 29. In general, it can be said that carrying capacity of bandwidth in a data center network is considered as one of the key factors in use of service and its capabilities; and also it is considered as a key variable in availability of services for increasing the attractiveness and willingness of users to use the service. Although, bandwidth upgrades contribute to increase the number of the final users of services, it can be seen that other restrictions such as data storage level in the center at the end of the third year have had a dramatic impact in reducing the number of users.

Figure 16.
Scenario 4: Improving the Carrying Capacity of Bandwidth in the Data Center – Waiting Online Users

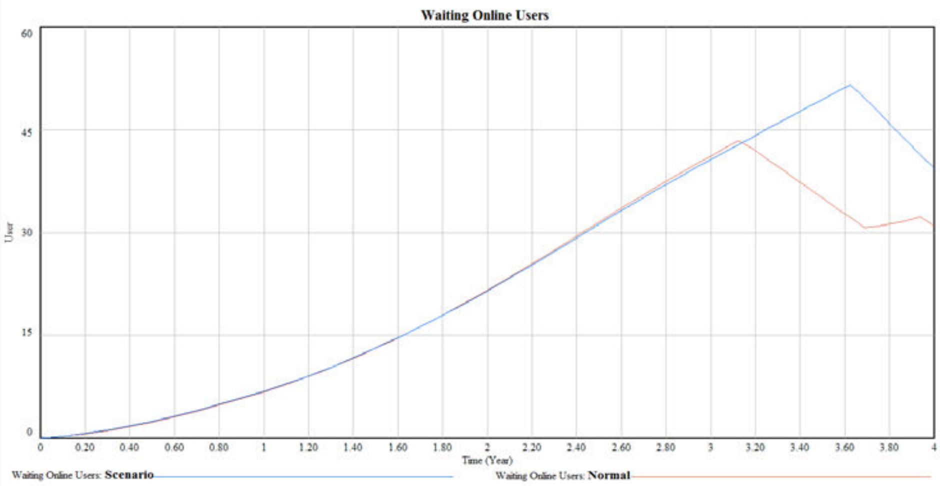
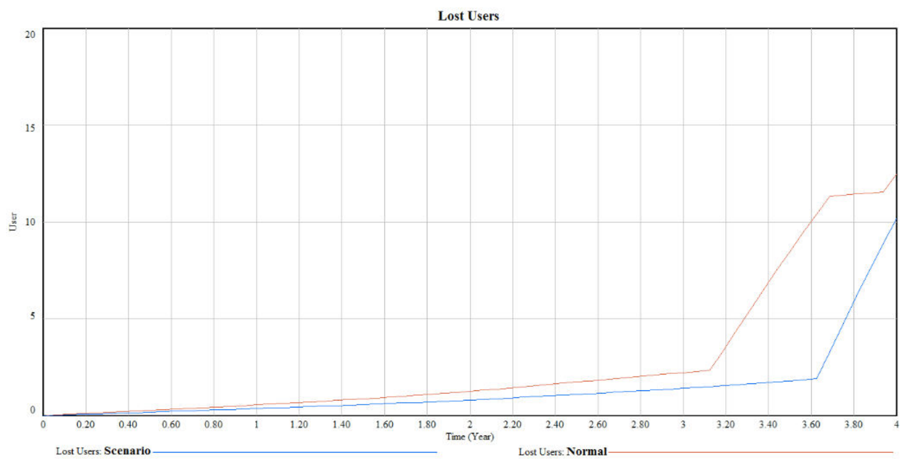


Figure 17.
Improving the Carrying Capacity of Bandwidth in the Data Center – Lost Users



Given that the maximum level of maintenance done in the data center is limited by available equipment and human resources, this scenario evaluates the effect of 50% reduction in the maximum feasible maintenance from the current value (600), which has evaluated the impact of this scenario on the level of maintenance done during the year and the level of services attractiveness. As it can be seen in the figure 31, this reduction in capacity, which is caused by increasing the rate of relative incomplete maintenance and also increasing the possibility of failures, will lead to a reduction in attractiveness of services.

Figure 18.
Scenario for Reducing the Maximum Feasible Maintenance - Feasible Maintenance

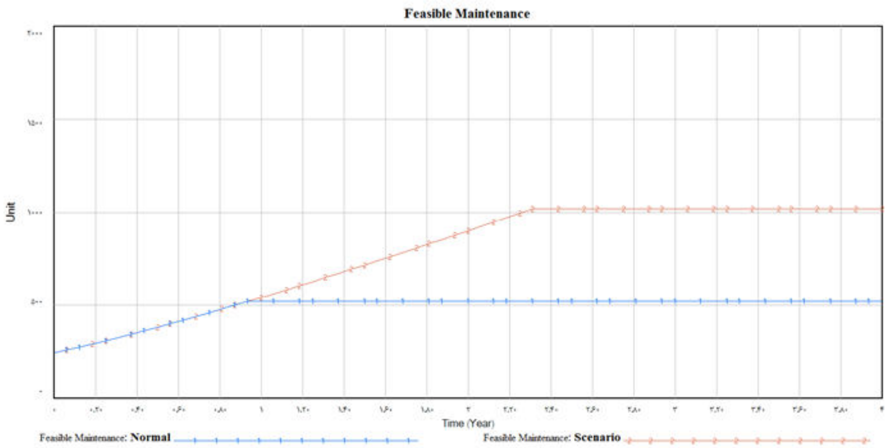
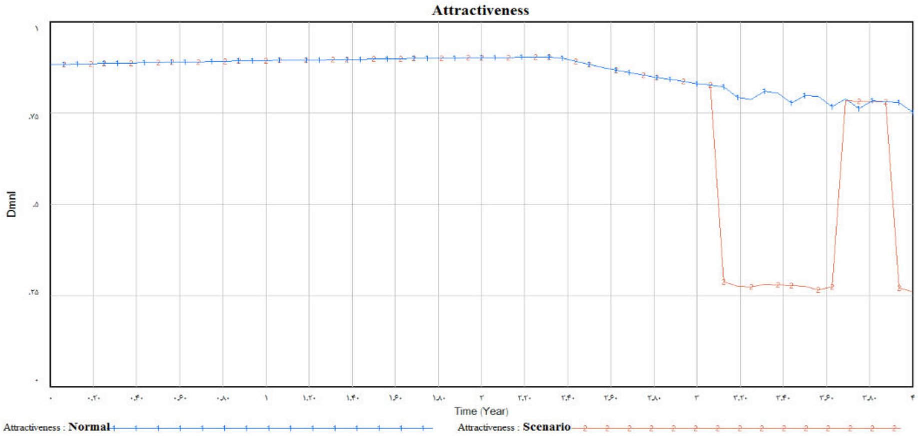


Figure 19.
Scenario for Reducing the Maximum Feasible Maintenance - Attractiveness



Conclusion

Nowadays, information- making is growing rapidly due to the developments in technology and organizations need to use information technology systems to carry out their missions, which has become the establishment of data centers to a requirement. In this vein, this study has tried to model the behavior of more than 125 variables affecting 15 main stock variables associated with data center by using system dynamics model. According to the conducted tests, it can be said that it explains well the changes in the main stock variables. TIA-942 was the main standard of availability in the data center, which was divided into 4 degrees. The evaluated data center had the ability to acquire Tier 4 during the first three years; since, in the fourth year, they were out of reach more than 40 hours, none of the sub-indicators of the TIA-942 standard were verified. According to the results, stock variables of bandwidth and storage follow from the common pattern of growth with higher bound and overshoot; and this oscillatory behavior begins respectively, after 2 years and 7 months and 19 days; and 3 years and 2 months and 29 days and it will continue by the end of the simulation. Behavior of total cost stock variables is ascending growth during simulation and current managers should bear in mind that the lowest amount of funds needed to attract during the second and third years of simulation will be an approximate amount of 85.5 million Toman and the highest amount of its will be around 104 million Toman during the first year. According to the available human resources, planned maintenance variable also could achieve a maximum rate of 600 maintenance programs after 1 year and 45 days that this amount caused attractiveness of services reach to the amount of 89 percent; and it experiences a reduced amount of 76 percent when a problem occurs in a data center and services lose. The studied scenarios are mentioned to the maximize reduced role of feasible maintenance number up to the 50 percent, in which ratio of incomplete maintenances increased due to the reduction and it raised the possibility of equipment failure by 60 percent. This causes difficulty in services and getting out of the reach for them. That's why the attractiveness of the services has reduced by 26 percent when the maximum feasible maintenance programs are reduced to half and this causes a decline in the number of online users in the data center that it will have a difference of 245 persons compared with the normal functioning of the services. According to the ascending growth of users, the optimal point of time was over 3 years and 22 days, in which the bandwidth rate will be equal to 149 Mbps, the storage rate will be equal to 1890 MB, and the processing load rate that system will endure, will be equal to 100% of the capacity. Also, the number of users using service at that time was equal to 1190 persons and the system was at its highest quality, i.e. 88% of quality, and service performance was at the yield value of 97.6%, as well. Also, regarding that bandwidth rate and occurred delay were considered as two key elements in the performance of data center networks; and finally delay influences on the user, it is recommended that industrial centers and organizations use regulation rules of service quality for prioritizing the information, which transfers to the network.

References

Association, T. I. (2014). TIA-942 Data Center Standards. Retrieved from Telecommunications Industry Association: http://www.tiaonline.org/standards

Awodee, O., &Akanni, A. (2012). Estimation of Required Bandwidth for Organizations. UNIASCIT,2(2), 257-262.

Beyeler, W. E., Conrad, S. H., Corbet, T. F., O'Reilly, G. P., & Picklesimer, D. D. (2005). Inter Infrastructure Modeling Ports and Telecommunications. Bell Labs Technical Journal,9(2), 91-105.

Cahyo, W., El-Akruti, K., Dwight, R. & Zhang, T. L. (2014). Managing maintenance resources for efficient asset utilization. AMPEAK Asset Management Conference (pp. 1-9). Victoria, Australia: Asset Management Council.

Genge, B., Kiss, I., & Haller, P. (2015). A system dynamics approach for assessing the impact of cyber-attacks on critical infrastructures. International Journal of Critical Infrastructure Protection, 3-17.

Hassan Naiyebi, E., Kiyani, B., Nori, S. (2008). "Improvement of Project Planning through Performance Modeling of Project by using System Dynamics Approach", First International Conference on the Strategic Management of Projects, Tehran: Sahrif University of Technology, Rezaee martyr Institute.

LeClaire,R. J., & O'Reilly, G. (2005).Leveraging a High Fidelity Switched Network Model to Inform System Dynamics Model of the Telecommunications Infrastructure. In Proceedings of 23rd International Conference of System Dynamics Society. 17-21 June 2005. Boston, USA: System Dynamics Society.

Liao, Y., Wang, Y., Wang, Y., &Tu, Y. (2015). Understanding the dynamics between organizational IT investment strategy and market performance: A system dynamics approach. Computers in Industry, 46-57.

Mccallun, J., Ranai, K. & Srinivasan, B. (1990). Estimating network communication speeds for office automation. Butterworth & Co, 13 (2), 99-107.

MesbahiFard, S.A., Dokhani, M., DadgarNiya, A. (2007). "Providing a Time Management Service for Improving the Performance of Wireless Ad Hoc Networks", Tenth Iranian Student Conference on Electrical Engineering, Isfahan: University of Technology.

Mirzaee, H. (2005). Providing Net Policy using Dynamic System, MA Thesis, South Tehran Branch of Islamic Azad University, Iran.

Nazareth, D., & Choi, J. (2015). A system dynamics model for information security management. Information & Management, 123-134.

NikPey, A. Torabi, S.A. (2012). "Providing a New Framework for Selecting a Suitable Portfolio of Performance Improvement Projects", The Ninth International Conference on Industrial Engineering, Tehran: Institute for Industrial Engineering, Khaje Nasir Toosi University of Technology.

Shah Qoliyan, K., Yosoufi, M.A. (2010). "Designing a Model for Evaluating the Efficiency of Electronic Banking Using System Dynamics", Shiraz: The First International Conference on Innovation and Management.

Sterman, J. (2013). Business Dynamics: System Thinking and Modeling for a Complex World, (K. Barar Pour et al., Trans.), Tehran: The Organization for Researching and Composing University Textbooks in the Humanities (SAMT).