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Research Paper

The Analysis of Mobile Phone Consumers' Behavior by Combining System Dynamics (SD) and Agent-based Modelling (ABM)

Navid Nadimi [1] **Abbas Toloie Eshlaghy** [2]

Abstract **The purpose of this paper is to prepare a hybrid simulation model of system dynamics (SD) - agent-based modeling (ABM) to investigate the mobile service consumers' behavior in the country. By using the suggested in this article, first the necessity to analysis consumers' behavior is explained and then the effective factors on mobile ecosystem which influence the consumers' behavior are explained. For each factor affecting on the ecosystem, related simulations were performed and then by combining system dynamics modeling - agent -based modeling, the behavior of mobile service consumers in the first operator of the country (Hamrahe Aval Company) was examined and finally the income affected by that behavior is analyzed. Results indicated that if no funds by the operator are allocated to the development of native applications and digital platform, after 2 years, the number of active customers of the operator will decrease because of the activities of cultural organizations. By the operator entering into the field of native application production and digital transformation, consumers tended to use more data services instead of voice calls, but because of different data and voice tariffs, the operator's income will not change much in the next 2 years. With the increase of marketing and advertising activities, despite the greater consumer inclination to use data, the main income of the operator decreases, which also needs more attention of policymakers in this area.**

Keywords *Ecosystem, Systems Dynamics, Hybrid Simulation, Agent-Based Modeling- Digital Platform*

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[1.] Department of Management, Central Tehran Branch, Islamic Azad University, Tehran, Iran
[2.] Department of Management, Science and Research Branch, Islamic Azad University , Tehran, Iran, Correspond Author : toloie@gmail.com

Introduction

Nowadays marketing is changing quickly in today's competitive society, the organization which has the mechanisms meeting these changes can be active. (Jaliliyan,1395). If competition increases the organization needs to keep its competitive advantages in order to not be left out of it. (Saremi,1389). During the last decade, the way brands relate to consumers has been changed by the actors in the field of communication in the world. There hasn't been so much attention before paid to customers before. Sectors such as banking and aviation focused only on sponsors and large transactions. But with the advent of social media, each interaction and transaction became more important. (Wang, J. 2013) operators have not focused much on customer service and this has led to a large number of subscribers decamping to the services of competing operators each year. Mobile operators have to study and conduct specific studies on the behavior of their customers at different time to maintain or increase market share and increase customer satisfaction. Analysis of customer preferences in the context of time helps operators to identify the factors affecting their consumer behavior, and the operator can by comprehensive analysis and more accuracy on the above factors and by providing solutions and policies to increase the effect of positive factors as well as reducing the effect of negative factors.

Background

(Al-Mashraei, 2020) in a study entitled "Analysis of customer turnover behavior in the mobile network industry through the push-pull framework" offers an approach with machine learning logic. In this paper, the performance of different reversal prediction models based on real data obtained from a partner company is compared. Prediction models include logistic regression, support vector machines, random forest and decision tree. (Chen ,2013) in an article entitled "Providing a search-based framework for predicting customer behavior in terms of remote payment" using data mining algorithms has adopted a strategy that uses the rules of

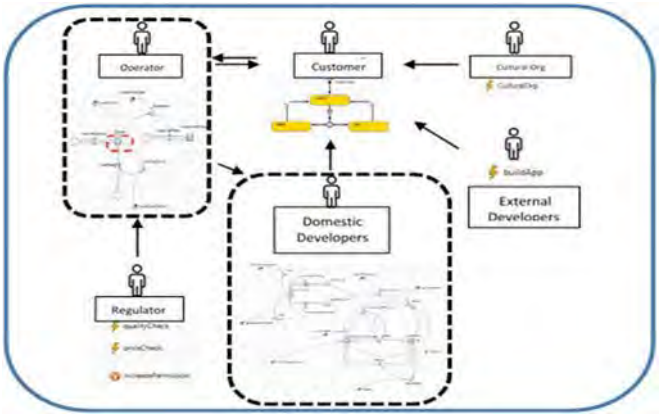
communication, clustering and decision tree Uses fixed line users to analyze data to create a delay forecasting system. This forecasting system can identify potential users who may not pay on time. In designing the proposed system, to formulate communication rules in the system, customer payment behavior analysis and analysis results were used to generate derived traits. Next, the clustering algorithm was used to segment the customer. Hidayati (2018) in the article "Customer Behavior for Mobile Service Providers" explains that learning customer behavior is one way to achieve customer satisfaction. Khanzadi (1397) in an article has determined a way to combine system dynamics and factor-based simulation approaches in the manufacturing industry. Na'ami (2015) in a study, by identifying the factors affecting consumer behavior and evaluating them using the opinion of experts, tries to use an analysis to examine the importance of the relationship between those factors. In the telecommunications and mobile phone industry of Iran, despite 3 mobile operators and competitors in the field of providing mobile services, analysis with the help of simulation methods will be very important. Because in Iran, in addition to technical issues and network quality, issues such as culture and consumption preferences over customer behavior are prominent. On the other hand, due to the infancy of the development of native applications and internal platforms and the interest of operators to enter this field, naturally the type of consumer behavior will be affected by the use of data services and voice calls.

Method

This research in terms of nature and method, it is descriptive-analytical one. Investigating the behavior of complex systems because of the existence of several components, factors and nonlinear and irrational interactions with specific feedback and delay cannot be analyzed alone with single simulation models such as system dynamics, discrete event simulation, agent-based modeling. Models' combination can sometimes help to understand complex systems, increasing modeling accuracy, and

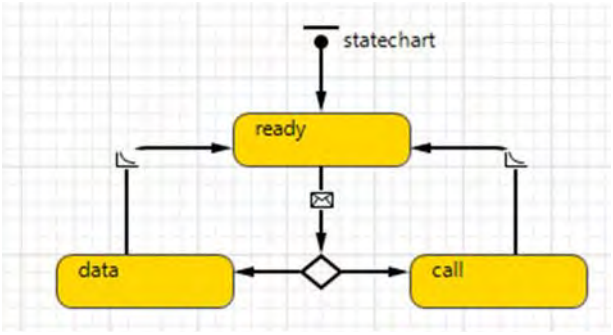
computational efficiency. Integrating system dynamics with agent-based modeling ideas prepares the potential to combine the strengths of the two methods and help increase modeling accuracy (Azimi, 1395). In current study in accordance with figure1 schemata of the model, which includes the factors and their relations, as well as the modeling method of each factor, which is finally presented as a hybrid model is represented? Then, each of the factors and how to check it according to its nature will be explained. Also, the dynamism of the mobile ecosystem environment because of the complex cross-structure of different effective factors is investigated by using the dynamics of systems and the complexity of the system due to relation between various factors by the solutions of the operating model. Finally, the system dynamics model and agent-based simulation are combined. First, the factors and variables (actors) of the mobile service ecosystem are identified by performing interviews and distributing questionnaires with Telecom experts, and according to the nature of each, they will be modeled. To select the appropriate method for simulation, (Burshchev,2017) stated that the same traditional approaches to simulation can be used if the problem can only be modeled with discrete simulation approaches and the dynamics of systems. But in cases where traditional simulation approaches are not able to model the problem and take into account all the complexities of the system, it will use agent-based modeling or a combination of agent-based modeling and traditional simulation methods. In the conceptual model (figure below), the relation of all factors involving in the mobile ecosystem and influencing on consumers' behavior, as well as how to model each factor is indicated. Operators and developers of native platforms have dynamic behaviors that use system dynamics to examine them. (Wallentin, 2016). In analyzing the behavior of other factors, agent-based simulation has been used.

Figure 1.
How to Model Agents as Hybrid SD and ABM



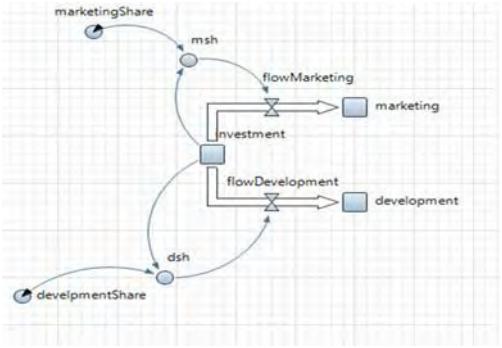
As mentioned above, the goal of this study is to investigate the behavior of mobile phone consumers in the country. It is obvious that the amount of income directly relates to the tendency of the operator's customers to use the service. Consumers are divided into regular customers and business customers, based on which their use of mobile services is different. This difference has been analyzed in terms of their use of call services and mobile Internet services. There are various factors in this ecosystem that the function of each of them leads to a change in the behavior of mobile phone users. These factors include operator, regulatory, external application developers, internal developers of digital applications and platforms, cultural Organizations. Because of the complexity of the case, the combined approach of agent-based modeling – system dynamics has been used to simulate and analyze the behavior of mobile phone consumers. AnyLogic simulation software was used to build the simulation model of the mentioned problem. In addition to supporting all three simulation approaches, the software also provides hybrid modeling. Six identified factors (service providers, regulators, external application developers, internal application developers, and digital platforms and cultural organizations) were created in the software environment. This factor is a multi-agent factor in the issue. It means that there is more than one factor that follows a certain behavior.

Figure 2.
Customer Agent Sstatus Chart



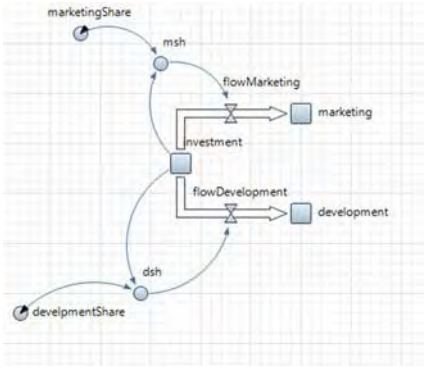
The operator agent in the issue in question is a single agent. This means that there is only one agent that provides call and Internet services. As mentioned, due to the complexities of this factor, its behavior needs to be implemented by causal loops and through the modeling of system dynamics. Figure 3 shows the system dynamics model of operator operating behavior.

Figure 3.
Intensity-operating Model of Native Application Developers and Digital Platforms



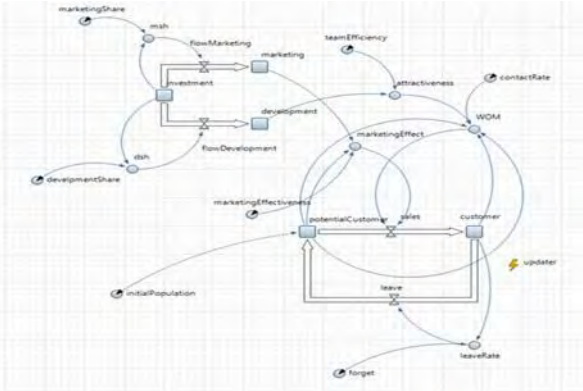
Since the attractiveness of the applications and platforms developed leads to greater customer engagement, this process is often generated by oral advertising, as well as the amount of money available as marketing is affected by performance (Marketing). It is necessary to complete the process of converting potential customers into actual ones, taking into account the above. The system dynamics behavior model of native application developers is shown in figure 4.

Figure 4.
Intensity-operating Model of Native Application Developers and Digital Platforms



Since the attractiveness of the applications and platforms developed leads to greater customer engagement, this process is often generated by oral advertising, as well as the amount of money available as marketing is affected by performance (Marketing). The system dynamics behavior model of native application developers is shown in figure 5.

Figure 5.
Dynamic Operating Systems Model for Native Application Developers



The more attractive the applications produced on the digital platforms, the more oral advertising in users of this application will be. Oral advertising is influenced by Contact Rate, which is defined by a parameter in the model. External application developer Agent provides an application at specific intervals

that leads to an increase in the conversion rate of potential customers to the actual operator. In order to influence the conversion of external applications on the conversion rate of potential customers to actual ones, a new parameter called International App is defined in the internal application developers' factor, which increases the conversion rate of potential customers to actual ones. Regulatory Agent in specific intervals determines the price increase license as well as the new quality level. The new quality level that the operator is required to comply with. The price increase permit is also determined by a variable. To validate the hybrid simulation model of the problem, we test the operator's daily income, which is the result of the use of voice calls and Internet data by ordinary and commercial customers, with real-world operator data. The number of samples is 360. To determine the appropriate test to perform the equality test of the means. of the outputs of the simulation model and real-world data, first the test of normality and data independence is performed.

Figure 6.
Q-Q Plot Diagram Related to the Daily Income of Ordinary Customers in the Real Environment and Model Environment

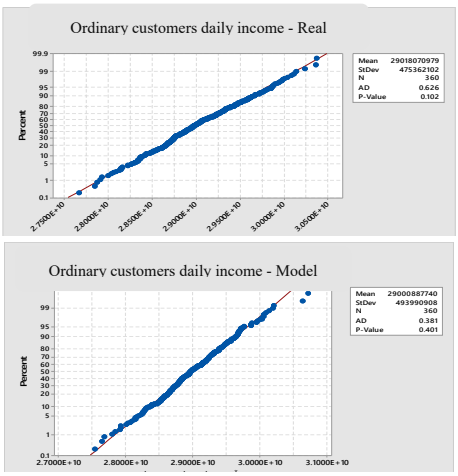
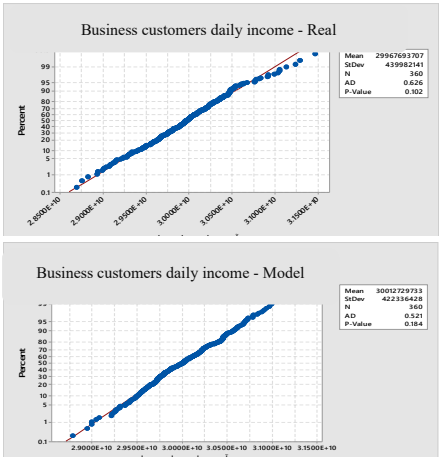


Figure 6 shows that the p-value is more than 0.05, and the normality of the data collected from the simulation model and the real world for the daily income of ordinary customers is accepted.

Figure 7.
Quantitative Chart of Daily Income of Commercial Customers in Real Environment and Model Environment



As we can see in figure 7, the p-value is more than 0.05 and the normality of the data collected from the business model simulating the daily income of commercial customers in the real world is accepted. Probably the most widely used statistical index of bivariate correlation is the Pearson torque correlation coefficient, commonly called the Pearson correlation. Now the hypothesis of independence of data on daily income of ordinary customers extracted from the simulation model and data extracted from the real world is examined using Pearson test.

Table 2.
Pearson Test Results for the Operator's Daily Iincome from Regular Customers

Pearson correlation	-0.015
P-value	0.775

Considering the p-value and being more than 5%, it can be concluded that the tested data are independent of each other and the assumption of data independence is accepted. Regarding the data on daily income of commercial customers extracted from the simulation model and the real world, the data independence hypothesis is also examined using the Pearson test:

Table 3.
Pearson Test Results for the Operator's Daily Income from Commercial Customers

Pearson correlation	0.003
P-value	0.957

Considering the rate of p-value and it being more than 5%, it can be concluded that the tested data are independent of each other and the assumption of data independence is accepted. Now, using the t-test, the hypothesis of equality of means is examined.

Table 4.
Estimation of T-test

`Sample	N	Mean	St Dev	SE Mean
Normal daily income - model	360	29000887740	493990908	26035607
Normal-real daily income	360	29018070979	475362102	25053783

In order to investigate the hypothesis of equality of means and to ensure the accuracy of work, the mean and standard deviation have been calculated for 360

samples of the operator's daily income from the consumption of ordinary customers in the model and the real world.

Table5.

Estimation of the Difference Between the Averages of the Two Communities

Mean	St Dev	SE Mean	95% CI for μ- difference
-17183239	690721004	36404193	(-88775505, 54409027)

Table 6.

Results of the Simulation Model and Real-world Hypothesis Test Regarding the Operator's Income from Ordinary Customers

Null hypothesis	H_0: μ_difference = 0	T-Value	P-Value
Alternative hypothesis	H_1: μ_difference ≠ 0	-0.47	0.637

According to Tables 5 and 6, the p-value value is assumed to be equal to the mean of the data extracted from the simulation model and the real world in terms of operator revenue from ordinary customers.

Table 7.

Estimation of T-test

Sample	N	Mean	StDev	SE Mean
Daily business Income-Model	360	30012729733	422336428	22259084
Daily Commercial-Real Income	360	29967693707	439982141	23189095

Table 7 shows the t-test estimate for the operator's daily revenue from commercial customers in the model environment and the operator's daily revenue from commercial customers in the real environment.

Table 8.

Estimation of the Difference Between the Averages of the Two Communities

Mean	St Dev	SE Mean	95% CI for μ- difference
45036027	609014837	32097900	(-18087509, 108159563)

Table 9.
The Results of the Simulation Model and real-world Hypothesis Test Regarding the Operator's Income from Business Customers

Null hypothesis	H_0: μ_difference = 0	T-Value	P-Value
Alternative hypothesis	H_1: μ_difference ≠ 0	1.40	0.161

Based on Tables 8 and 9, the p-value is assumed to be equal to the average of the data mines extracted from the simulation model and the real world in terms of operator income from business customers. Finally, the validation of the hybrid simulation model of the dynamic-factor system is accepted at a significance level of 5%.

Findings

In this section, the outputs of the hybrid model are analyzed and for this purpose, the degree of its adaptation to the real situation is compared.

First analysis: the model of maintaining the current situation in the case of non-allocation of budget to the development of native applications and digital platforms: In this scenario, the simulation model will be implemented for 730 days, equivalent to two years. The external application developer factor provides an attractive application in the range of 300 to 365 days using the uniform distribution function and leads to an increase in the share of Internet usage by 2% to 10%. On the other hand, cultural organizations provide advertisements every month in order not to overuse the mobile phone. The results of this scenario are as follows.

Figure 8.

Graph of the Share of Ordinary and Business Customers' Use of Voice and Internet Calls

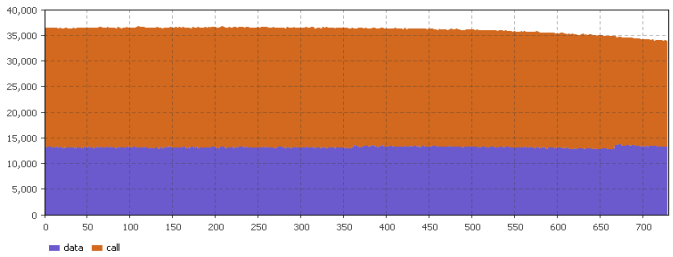
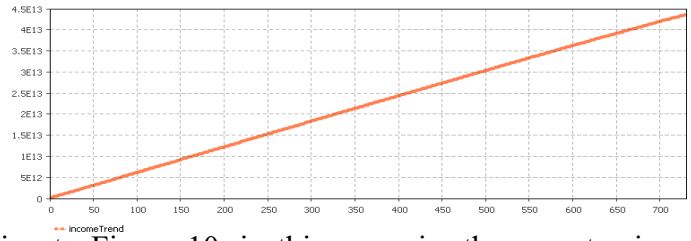


Figure 8 shows the share of regular and business customers' use of voice and Internet calls. The model simulated customers' share of contact 67% and their share of Internet 33%. At the end of the second year, this share has changed to 62% of calls and 38% of Internet (data).

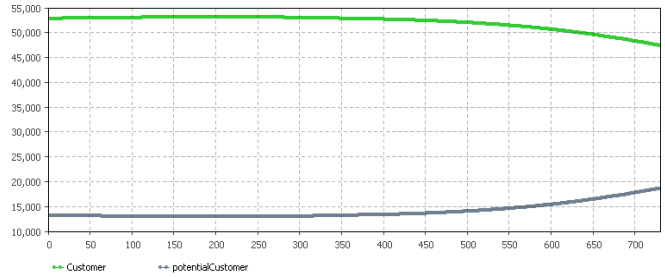
Figure 9.

Operator Revenue Chart



According to Figure 10, in this scenario, the operator income was 43,570 billion at the end of the second year. However, because of the reduction in the number of active customers due to the influence of cultural institutions on the consumption of current customers, the income has a decreasing slope.

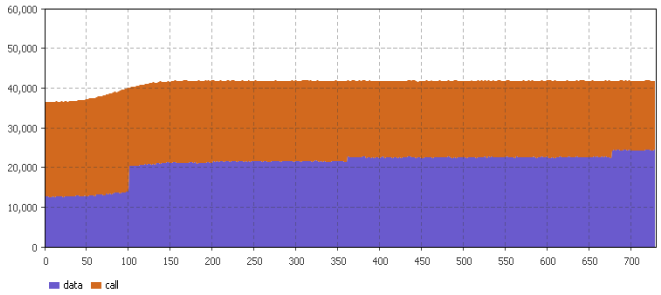
Figure 10.
Graph of the Number of Active (actual) and Inactive (Potential) Customers



Although the arrival of attractive foreign applications, due to the activity of cultural institutions from the first year onwards, the number of customers who switch from active to inactive has increased, which in the chart shows the number of active and inactive (potential) customers.

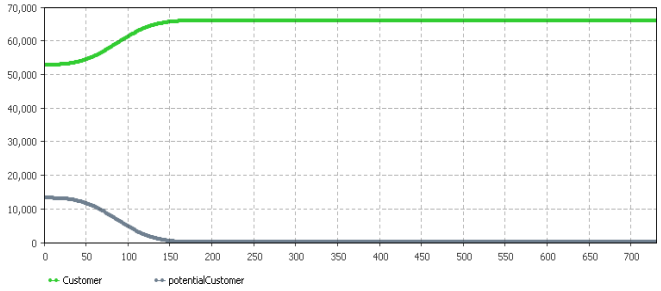
Second Analysis: **the current situation model in the budget allocation mode to the development of native applications and digital platforms.** As in the previous scenario, the simulation model will be implemented for 730 days, equivalent to two years. The external application developer factor provides an attractive application in the range of 300 to 365 days using the uniform distribution function and leads to an increase in the share of Internet usage by 2% to 10. The operator allocates 1% of annual income for the development of native applications and digital platforms. The number of potential customers of the operator in the first moment of the simulation is equal to 80% of the total customers. The annual regulator authorizes the operator to increase the price by 10% per year and also requires the operator to increase the quality of its services by 5% per month. The findings of this scenario are shown as below:

Figure 11.
Chart of Share of Ordinary and Business Customers' Use of Voice and Internet Call (Data)



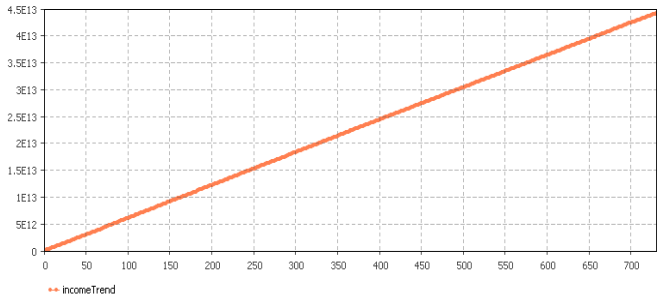
Based on Figure 12, as we can notice the most important change in this scenario compared to the previous one is the change in the share of Internet usage (data). In the first scenario, at the end of the second year, the share of customers in call was 62% and their share of Internet (data) was 38%. But in this scenario, at the end of the second year, the share of customers from calls decreased to 57% and the share of Internet use increased to 42%.

Figure 12.
Graph of the Number of Active (Actual) and Inactive (Potential) Customers



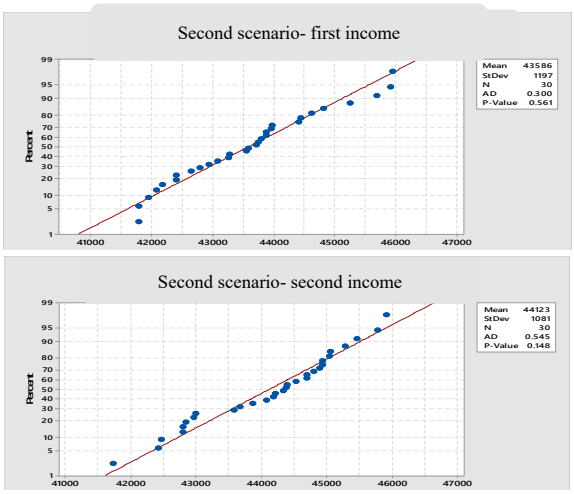
As it is indicated in figure 12 (number of active and inactive customers), the process of converting inactive to active customers due to the attractiveness of digital platforms and the development of internal applications and oral advertising of customers using this application is increasing so that at the end of the fifth month, almost 98% of customers use the services of the operator.

Figure 13.
Operator Income Chart



According to figure 13, due to this increase in service users, the operator's income will increase from 43.586 billion Tomans at the end of the second year to 44.123 billion Tomans, which is a growth rate of approximately 1 percent. In order to obtain a better result than the effectiveness of the operator's participation in the development of internal applications and digital platforms on the operator's income, we test the results of 30 times the simulation model of the previous scenario and this scenario for 2 years. The results are as follows:

Figure 14.
Test the Normality of the Operator Income Distribution in the First and Second Scenario



Considering figures 14 and the p-value and greater than 5%, the assumption that the data is normal is accepted. Now we analyze the data independence hypothesis.

Table 11.
Pearson Test Results for Operator Daily Income from the First and Second Analysis

Pearson correlation	0.057
P-value	0.764

The assumption of data independence is also accepted with respect to the p-value. According to the above results, using t-test, we analyze the hypothesis of equality of means. Here are the findings:

Table 12.
Estimation of T test for Operator Daily Income from the First and Second Analysis

Sample	N	Mean	StDev	SE Mean
Scenario 2 - Income from the first analysis	30	43586	1197	218
Scenario 2 – income from the second analysis	30	44123	1081	197

Table 12 shows the t-test estimation for the operator's daily income from the results of the first and second analyzes by running the simulation model 30 times.

Table 13.
Estimation of the Difference Between the Averages of the Two Communities (Daily Income of the Operator From the First and Second Analysis)

Mean	St Dev	SE Mean	95% CI for μ- difference
-536	1566	286	(-1121, 48)

Table 14.
Test Results of the Hypothesis of Data Independence from the Operator's Daily Income in the First and Second Analysis

Null hypothesis	H_0: μ_difference = 0	T-Value	P-Value
Alternative hypothesis	H_1: μ_difference ≠ 0	-1.88	0.071

Considering Tables 13 and 14, since the p-value is more than 5%, it can be concluded that at the meaningful level of 5%, there is no significant difference between the operator's income in the first and second scenarios of this paper. Therefore, it can be concluded that the operator's activity in the development of native applications and digital platforms in 2 years does not lead to a significant increase in operator income. - In the second analysis, if the operator decides to invest in the development of native applications and digital platforms and allocate 1% of its income to this, this activity will increase the share of customers using Internet services (Data) is 24%. Also, almost 98% of the operator's customers switch to active mode because of the attractiveness of these applications.

Conclusion

In the first scenario, which is the actual position of the reviewing system, it was observed that after 2 years because of the activities of cultural organizations, the number of active customers of the operator will decrease by 8%. The operator's revenue also has a downward slope due to active customers' reduction and the regulatory necessity to increase the quality of services. The role of foreign applications in changing the share of use of call and Internet services (data) is remarkable, so that at the end of the second year, the share of use of Internet services (data) has shown a 5% growth. Obviously, the income and share of active customers of the operator in this scenario has reduced and the operator needs to start improving activities to increase income and keep the share of active customers, which will be analyzed in next scenarios. In second scenario, the operator decides to invest in the development of native applications and allocates 1% of its income to this. This activity raises the share of customers using Internet services (data) by 24%. Also, almost 98% of the operator's customers change to

active mode because of attractiveness of these applications. The considerable point is that despite increasing the share of active customers, the operator does not change its revenue. Because the share of the use of call and Internet services has also changed in this scenario and the amount of revenue of the operator from the data location is lower than the income from the customer call. The non-change of operator income was also examined by a statistical test and the lack of impact of operator participation in the development of internal applications on operator revenue was confirmed. It should be taken into account that the operator does not change income despite increasing the share of active customers. Because the share of the use of call and Internet services in this scenario has also changed and the amount of operator income from data is less than income from customers' call. The operator did not change its income by statistical test and the lack of significant impact on the operator's participation in the development of internal applications and the production of digital platforms over the next 2 years on the operator's income was confirmed. Considering that the simulation of this system has been performed in order to analyze the revenue sensitivity of the mobile operator in the period up to the next 2 years, it is suggested that this simulation be performed in a wider time horizon and the results be reviewed.

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