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Analyze the Effect of the Maintenance Activities on the Internet Sustainability by Using 2k Factorial Experiment Design

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Abstract
Nowadays, the internet and social networks become more popular than ever. People in all ages use the internet and communicate by that. One of the most terrible events in our daily life is to disconnect from the internet and lose the connections. It may also influence on the economics; so the sustainability in this area is necessary. Internet service provider companies are the executors of selling and maintaining the internet bandwidth. Some activities perform to maintain the corrupted internet ports. In this paper, the effect of maintenance activities on the internet sustainability is analyzed. This paper also discusses the three important maintenance activities and compares each of them with two different methods. The aim of this paper is to illustrate whether these three factors effect on the internet sustainability or not. 2^k design procedure was used to analyze the results.

Keywords
Maintenance activities, Internet, Sustainability, 2^k factorial experiment design, Design of experiment (DOE)

1. Introduction

By technology development in recent years, the rate of using internet has been increased. People use internet to satisfy their demands, such as: communication, buying things, finding jobs, scientific research, playing online and much more. Every day, the importance of internet is become more and more. For using internet, the internet service provider's companies (ISP) should provide a good platform. It is necessary for the telecommunications companies to apply some equipment. By utilizing the equipment, like other machines and devices, the maintenance program needs to be applied. The aim of maintenance is to increase the life cycle of devices [1]. Many methods such as regression analysis, experimental design, mathematical model, simulation and much more can be used to explain the maintenance effects policies [2]. Last minute maintenance can effect on operation performance, activity scheduling and also reduce the performance of spare part management[3]. Economic production quantity, statistical process monitoring and also maintenance were the most important implication in industrial places to maximize the productivity [4]. The most important role to minimize the breakdowns is being punctuality and well time maintenance [5]. Increasingly the thinking of sustainability becomes important in the design of Industrial Product Service Systems (IPSS) especially in the field of maintenance which can help us to reduce CO_2, increasing the lifetime of whole system with more efficiency [6]. Maintenance is intransitive when we want to use devices and execute with more efficiency in its life time. One of the most important ways to minimize the total costs is applying maintenance policy [7]. An important part of serious and costly systems is maintenance which can keep system running well with best function and ensure the safety [8]. By growing the industries and the competitive pressures, product's life cycle needs to be optimized; and nowadays, life cycle engineering and maintenance become more necessary and essential [9]. It can illustrate that maintenance is one way to reduce costs and increase the productivity, so in many cases and many industries, researchers used that.

Maintenance can contribute considerable operating costs in an organization. It is considered as a main base of the organizational performance. Zhao and tang [10] wanted to schedule the maintenance activities to minimize making span and to solve this problem by polynomial time algorithm. Pure thinking can be incorporated into maintenance activities through applying its ideology and practices [11]. Yoo and lee [12] tried to find the best schedule for maintenance activities for parallel machines in order to reduce the cost and time-consuming.

The maintenance activities can decrease time and cost in industries [13]. Some studies have defined that strategic planning should be applied to increase productivity and efficiency despite the maintenance activities in manufacturing. Also, maintenance activities are important in analyzing the current situation and planning for future activities [14]. Maintenance activities are identified as critical for both the operator safety and the system safety and reliability, but it was difficult to find the maintenance workers in this case and also there was a little analysis in this field [15]. When dealing with climacteric physical property, it is very significant to monitor some parameters just to apperceive and foretell the possible time to break and thus appoint a preventive maintenance activity avoiding the unfavorable failure incidence and its outcomes. Pursuant to continuous data preparing during the time about selected parameters, it is possible to see orientation and specify time to failure, assuming a pre-defined value as the critical one, corresponding to asset failure [16]. In manufacturing process for increasing the effectiveness of whole product and ensuring the product quality, maintenance activities become more necessary.

Also each machine needs several maintenance activities to perform better [17]. Huang and yi huang [18] believe that maintenance activities are important for bridge safety and can motivate traffic jams and maximize the costs. In order to minimize the costs during the bridge maintenance activities, they introduce the concept of concurrent element maintenance. Machines and devices in the systems need multiple maintenance activities with different ways to increase the productivity and to improve the products. But because of the constraint in maintenance budgets, the best ones should be applied [19]. In multitude actual production systems, machines may be unavailable because of breakdowns or preventive maintenance activities, so complementing lot-sizing and scheduling with maintenance planning are required to model real manufacturing conditions. Two variants are considered to be dealt with the maintenance activities. First, the beginning moments of maintenance duties are fixed while in the second one, maintenance must be carried out in a given time window [20]. Akbarzadeh Khorshidi et al. [21] used genetic algorithm to optimize a model which developed the decisions on both optimal redundancy allocation and best maintenance activities for reliability allocation. The optimization model is to maximize system reliability and minimize system cost simultaneously. On going operation of pipeline systems contains remarkable utilization in audit and maintenance activities. The cost-effective safety management of such systems involves assigning the optimal value of resources to inspection and maintenance activities, in order to control hazard [22]. The progress of system reliability depends on its construction as well as on the evolution of its ingredients reliability. Component senile is forcefully affected by maintenance activities [23].

Maintenance can be considered as the major enabling system to hold the physical part of a target in which it can be accomplished the demanded function. In that procedure, whatever the department is, workers carrying out maintenance activities are subject to various hazards [24]. Cost prediction of maintenance activities needs an expert leader and great details to make the automation of such an activity unwieldy. Thus a stochastic process will be needed to approach the problem of predicting the refusal of the service arisen from any required maintenance [25].

Esen et al. [26] used 2^k factorial experiment method for testing the motors and selecting the best one for the goal requirements. Ravandi et al. [27] used 2^k factorial experimental design and numerical modeling to measure the productivity of dummy water curtain in several situations. 2^k full factorial designs may be prohibitively expensive when the number of factors k is large. The most popular technique developed to reduce the number of treatment combinations is the fractional factorial design; confounding the estimation of the model parameters which naturally results in various resolution and aberration levels [28]. Abdul-Wahab and abdo [29] applied 2^k factorial experiment design to analyze the effect of five agents and their influences on the blow-down flow and the performance of each unit in various conditions and to illustrate the optimal results with this method. The main task to analyze the 2^k factorial design is to estimate the 2^k effect. It was executed when M conditions were required to be estimated [30]. Wang and usher [31] presented a factorial experiment design to study the setting used to exert Q-learning to the single machine, dispatching principle selection problem. Lee et al. [32] applied fractional factorial design to introduce an effective and structured methodology for carrying out a biometric system sensitivity analysis.

Nowadays, access to internet is very critical and important. Every day we can see lots of innovations in this scope which simplify accessibility to the internet world wide [33]. It shows that sustainability is necessary to access to the internet.

By researching and talking to the experts, we found 3 most important maintenance activities according to the high rate of damages. The importance of sustainability in this field motivates us to find the best way to maintain this important equipment. When finding the importance of each factor and the relations between them, the maintenance activity will be determined. According to the literature review, this research has never been worked on before and stimulated us to write this paper.

The rest of the paper follows as: Case study that we describe the place and the maintenance techniques that apply there. Then Methodology, which we introduce the way to analyze the data. After that, we can see the effect of each factors and finally conclusions.

2. Case Study

This work applied in one of the largest ISP companies in Isfahan called Saba net. In this company, when the subscribers buy a service, company’s experts used to go to telecommunications companies and proper the equipment. After some days or months, these devices depreciate and need to be maintained. The devices may have several problems but we found the most common errors in these devices by interviewing experts. We suppose each of these errors as a separate factor. Factor A is for the bulkhead errors. In this company, experts use two different models of bulkhead. Data cables need to be placed in these bulkheads. The maintenance of each of these bulkheads is different.

Factor B illustrates the type of splitters. Some splitters are maintainable but the others are difficult to be maintained. Different companies may use different types of splitters. But in this case study, three types of splitters have been analyzed that we did our experiment on two most common of them.

Factor C describes how an expert snips the data cables on bulkheads. This maintenance activity is one of the specialized activities that totally refer to each expert because of the power of using this work and also the spotless of the sniper tool. There are two types of snipping methods.

In all three factors we want to test two types of maintenance. The data which was collected in two months are reported by maintenance experts. Table 1 shows the number of maintenance activities collected in last two months with both maintenance types that four experts used and reported. The number in each table shows the amount of maintenance in each type. For example, 17 in the bellow table means that there were 17 maintenance activities on bulkhead 2 with type 1 snipping and in splitter 1 in last two months.

Table1. Number of maintenance activities in last two months

	Factor B	Splitter 1		Splitter 2	
	Factor C	Snip1	Snip2	Snip1	Snip2
Factor A	Bulkhead 1	15	7	9	3
		16	9	10	2
		16	6	9	4
		19	10	11	4
	Bulkhead 2	15	4	8	3
		16	7	9	2
		14	7	11	3
		17	9	8	4

The mean numbers of maintenance activities in last two months are illustrated in Figure 1.

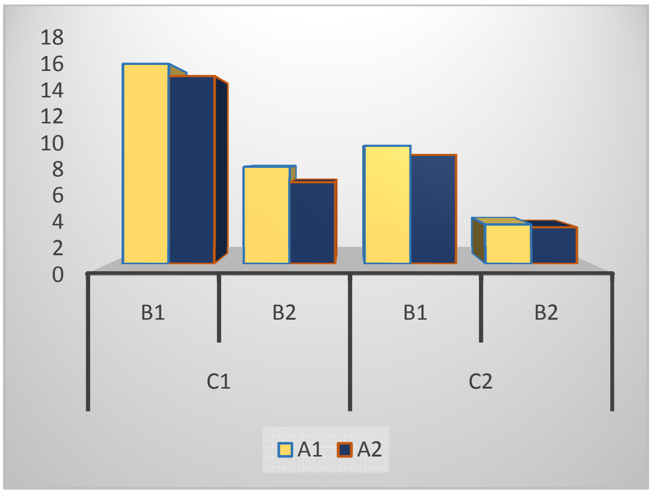

Figure1. Mean number of maintenance activities

In other sections we describe how these factors effect on each other.

3. Methodology

Design of experiment methods has been applied to solve the problems with various types of uncertainty, different productivity requirements and much more. Factorial design is one of the DOE methods. 2^k design can assess the 2^k mean solutions [28]. Many researchers used 2^kfactorial design to analyze their problems. Gonçalves et al. [34] used 2^k factorial design to demonstrate the optimal solution among eight different values which influence the performance. This work compares accuracy, time and detection value. Erickson and Liao [35] analyzed the effect of different input factors like flow disturbers, catalyst size and reactant flow, using 2^k factorial experiment design.
Because of the types of data collected, we apply 2^3 factorial experiment designs. Table 2 shows the first round of the factorial experiment design.

Table2. First round of 2^k factorial experiment design

Combination	Illustrate				Sum
1	15	16	16	19	66
a	15	16	14	17	62
b	9	10	9	11	39
ab	8	9	11	8	36
c	7	9	6	10	32
ac	4	7	7	9	27
bc	3	2	4	4	13
abc	3	2	3	4	12

The standard formulas of 2^k factorial experiment design were illustrated on equations 1 to 8.

$$SS_A = \frac{[-(1) + a - b + ab - c + ac - bc + abc]^2}{n.c^2} \quad (1)$$

$$SS_B = \frac{[-(1) - a + b + ab - c - ac + bc + abc]^2}{n.c^2} \quad (2)$$

$$SS_C = \frac{[-(1) - a - b - ab + c + ac - bc + abc]^2}{n.c^2} \quad (3)$$

$$SS_{AB} = \frac{[+(1) - a - b + ab + c - ac - bc + abc]^2}{n.c^2} \quad (4)$$

$$SS_{AC} = \frac{[+(1) - a + b - ab - c + ac - bc + abc]^2}{n.c^2} \quad (5)$$

$$SS_{BC} = \frac{[+(1) + a - b - ab - c - ac + bc + abc]^2}{n.c^2} \quad (6)$$

$$SS_{ABC} = \frac{[-(1) + a + b - ab + c - ac - bc + abc]^2}{n.c^2} \quad (7)$$

$$SS_{Error} = SStotal - SSA - SSB - SSC - SSAB - SSAC - SSBC - SSABC \quad (8)$$

4. Results and Discussion

We suppose α=0.05 for F and according to the 2^k factorial experiment design method, if the $F_{0.05,\ 1,\ 24}$ is lower than the evaluated F, then, that parameter(Source of changes) affects the sustainability and if it is upper than that, then, it doesn't have any effect.
In Table 3, the result of 2^3 experiment design has been illustrated.

Table3. Results of 2^3 designs

Sources of changes	Degrees of freedom (df)	SS	MS	F
A	1	5.28125	5.28125	2.5223
B	1	236.5312	236.5312	112.97
C	1	442.5312	442.5312	211.35
AB	1	0.78125	0.78125	0.3731
AC	1	0.03125	0.03125	0.0149
BC	1	11.28125	11.28125	5.3880
ABC	1	0.28125	0.28125	0.1343
Error	24	50.25	2.09375	-
Total	31	746.9687	-	-

$F_{0.05,1,24}$ equals 4.26. So parameter B and C and BC affect the internet sustainability and the other source of changes doesn't effect on that.
As it discussed before, parameter B contains splitter model and parameter C is kind of snipping that the experts use. So the BC parameter means when the expert snips and uses one of those splitters, the internet sustainability may be better or worse.
Before applying this methodology, when we discuss with Sabanet's experts, they think parameter AC maybe the most common reason of disconnecting from the internet; but this research, based on their data, shows that parameter AC doesn't have any effect on internet sustainability.
Finding the main reason of disconnecting from the internet can help both Internet Service Providers and their customers to have more satisfaction and gain more profits. Sustainability in this area can help people and business to find the best chance to do their activities in all cities and countries.
Interaction diagrams describe how a group of objects collaborates in some behaviors typically a single use-case. The diagrams show a number of example objects and the messages which are passed between these objects within the use-case.

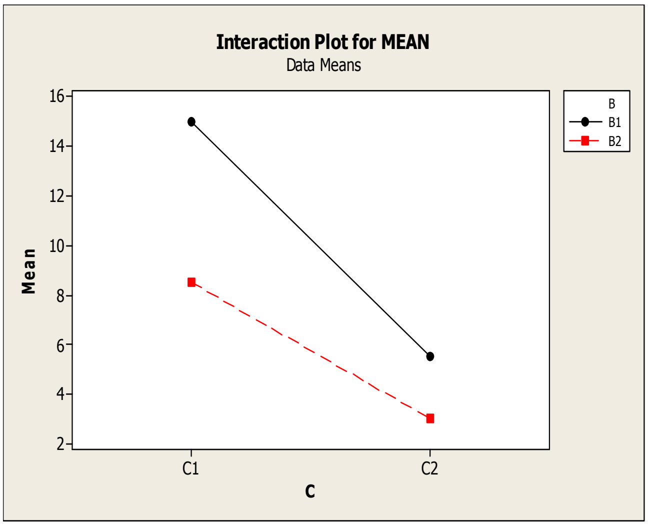

Figure2. Interaction plot for BC

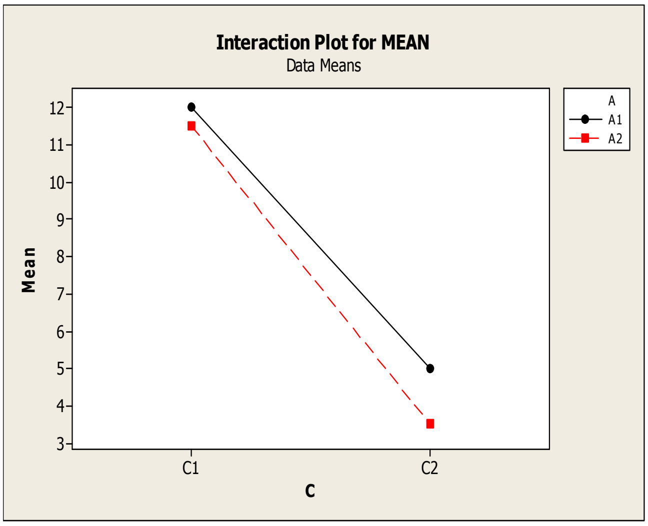

Figure3. Interaction plot for AC

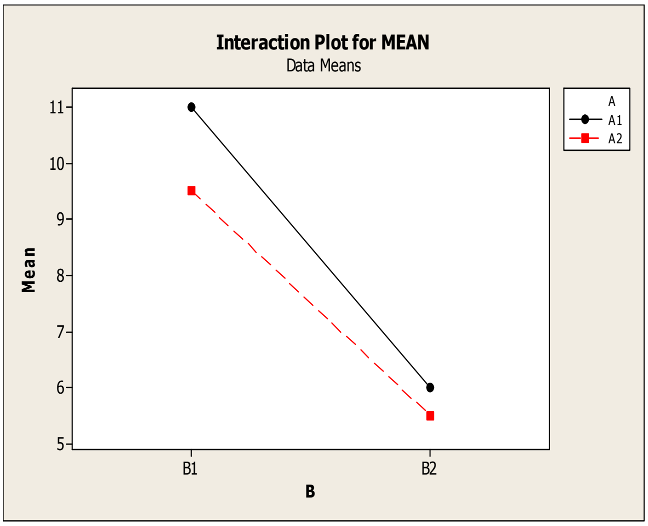

Figure4. Interaction plot for AB

Figures 2 to 4 show the interaction between each parameter that said before which was determined and calculated in last Table. These plots show that there is a big interaction between BC parameters that specified on Figure 2.

Like what we calculated, AC and AB don't affect the internet sustainability and the interaction plot illustrates them, too.

These interaction plots help us to visually understand how these factors effect on each other. For better understanding that how each factor can affect internet sustainability with different types of maintenance activities, we use main effect plot of each factor to illustrate the effect of each of them in two types of activities.

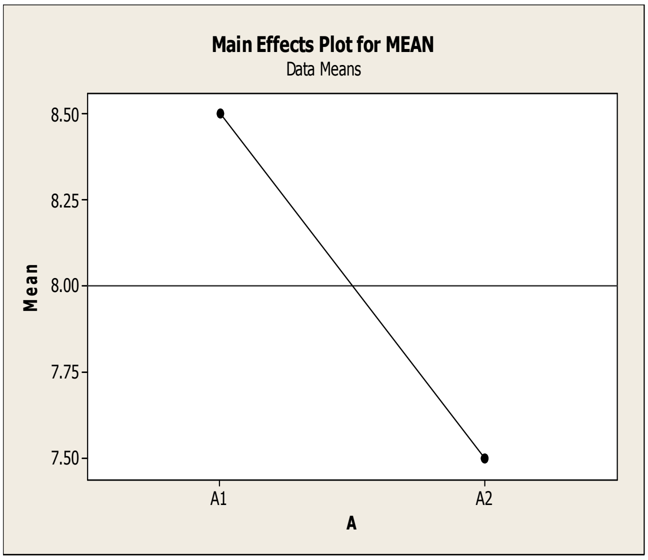

Figure5. Main effect of A

Figures 5 to 7 specify the main effects of each parameter when experts use different types of maintenance activities on internet sustainability.

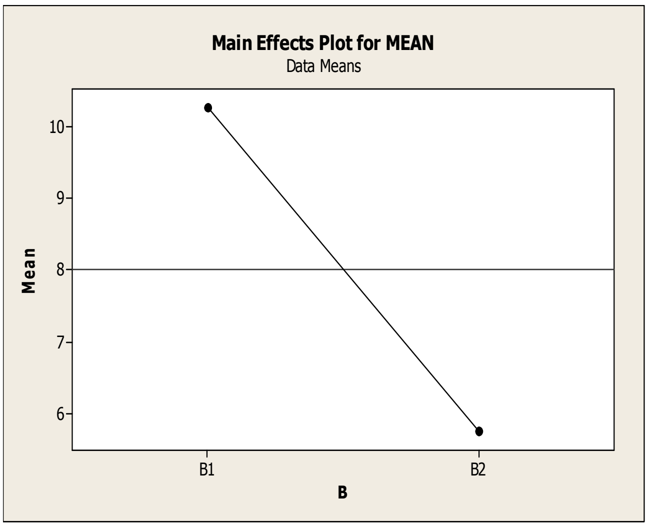

Figure6. Main effect of B

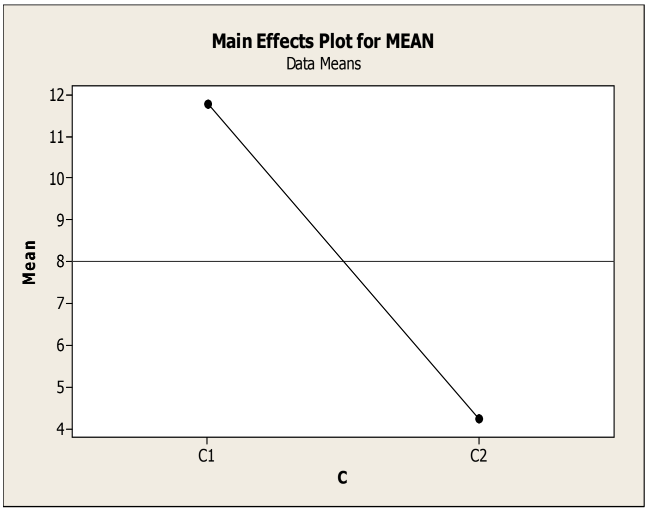

Figure7. Main effect of C

It is defined that the difference between each type of maintenance activities in parameter A is too little and because of this, it doesn't have any effect on internet sustainability.
In spite of it, factor B and C show more mean than factor A and as it was calculated before, they are those maintenance activities that affect internet sustainability.

5. Conclusions

These days, connecting to the internet has become more necessary and people need to use it to communicate with each other, find jobs, register, sell, buy and much more. We can see people in any ages which use their computers, mobiles and etc. in order to connect to the internet.
Some enterprises grow to satisfy this demand which called ISP. In order to gain more profits, they need to find more customers and try to satisfy their demands. One of the most indicative of satisfaction in this field is having more connecting time with minimum rupture.
Almost always disconnecting comes from the failure of the devices. ISP experts fix these devices with various maintenance activities and each method can be more useful. By analyzing the numbers and the reasons of failure in last two months in Sabanet Company, we found three most common reasons of failure: the bulkhead types, type of snipping that expert's use and the splitter model.
Each of these parameters can harm the sustainability of the internet and cause to dissatisfaction of the customers and also decrease the benefit of the company.
To find the main reason of the maintenance activity which can decrease the internet sustainability, we use 2k factorial design to illustrate that each of these parameters can directly affect internet sustainability. This method is less used in the field of maintenance and sustainability but it can show the reason of failure results very efficiently.
The results show that the type of bulkheads doesn't affect internet sustainability, but the type of snipping used to snip data cables and the splitter model can affect sustainability. Also when two maintenance activities are done in one port, the sustainability may be changed. By this study, we found out if the splitter and the snip are used in one port, it can be effective on the internet sustainability, but the other activities can't harm this field.

This work can help ISP to use the best maintenance activity and try to satisfy their customers to gain more income.

In future, researchers can try more maintenance activities like type of data cables and network cards to find better results. Also this work can be used in other fields of maintenance to find the main effective parameter of device failures. Other DOE methods can be applied and compared with this method.

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