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Taguchi Method to Measure the Impact of GPSR Routing Protocol Parameters in VANET Performances

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Abstract

Background/Objectives: Routing protocols play an important role in the performances of Vehicular Ad Hoc networks (VANET). Routing protocols procedures are controlled with a set of parameters from being dragged to undesired situations such as flooding the network with unnecessary overhead. These parameters have a direct impact on the efficiency of a routing protocol and the overall network performances. The impacts of these parameters on the network performances are less considered in the literature. **Methods:** This paper proposed the Taguchi delta analysis to measure the impact of Greedy Perimeter Stateless Routing (GPSR) protocols parameters on the performances of VANET. Then, the obtained results are investigated with iterative method to validate the Taguchi observations. Further, an offline optimization of the GPSR parameters is evaluated by performing Taguchi SNR method for fine-tuning the GPSR routing parameters. **Application/ Improvements:** GPSR with Taguchi tuned is compared with GPSR configuration in a realistic VANET scenario. The obtained results showed that, GPSR with Taguchi configuration outperformed the GPSR in terms of delay and PDR on the simulated scenarios.

Keywords: GPSR, Optimization, Routing Parameters, Taguchi Method, VANET

1. Introduction

Vehicular Ad Hoc Network (VANET) presents a technological solution to improve road transportation systems. VANET consists of vehicles on the road nodes called On Board Units (OBU) and Road Side Units (RSU), where information is transferred in a multi hop fashion to a desired destination. OBU as vehicles are tending to travel in geographical distances, which implies their engagement to different network topologies and scenarios. This fact conveys the need for robustness in the design of protocols to the adhered multi-scenario phenomenon in VANET. Particularly, a routing protocol that is designed for city VANET might not perform in highway or rural area, as the network topology and requirements are not similar. Thus, it is required for the routing protocol to adapt or change it is behavior for different network scenarios.

Routing protocol behavior describes the protocols mechanism, which is controlled by a set of routing parameters such as *Beacon_interval* and *neighbor_validity_time* in GPSR[1]. These parameters have a direct impact on the network performances[2–4]. For example, higher frequent of Beacons increases the freshness of routing information, but induces more protocol overhead in the network. Consequently, it is necessary to fine-tune the Beacon_interval value according to the network situation. Toutouh[5] proposed an optimization to OLSR routing parameters, and concluded that optimizing the OLSR configurations improves VANET performances. This study motivated the works in this paper for further investigate the impact of routing parameters on the network performances. Accordingly, the work in this paper firstly investigates the effects of three GPSR parameters in two VANET scenarios. This is to highlight the correlation

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between these parameters and VANET scenario requirements. Secondly the Taguchi delta analysis method is utilized to quantify the effect of GPSR routing parameters in VANET. Lastly, Taguchi delta analysis observations are used to determine the fine-tuned routing parameters of GPSR, and propose an optimum configuration of GPSR to improve its efficiency for different VANET scenarios.

The proposed method is applied to two VANET scenarios (city and highway) for further investigate the protocols configurations in respect to topology parameters. The results concluded that, network scenario is a major factor to be considered for configuring routing protocol parameters. And, the routing protocol's parameters are unequally affects the network performances.

VANET routing protocols performances evaluation had been a major topic for many works in the literature[6,7]. Accordingly, these protocols are classified into topological and geographical routing mechanisms, and their performances are evaluated against different network parameters including mobility, scalability and network traffic. Indra *et al*[8] proposed a taxonomy based VANET routing protocols classification and highlight challenges and issues are to be considered for designing a routing protocol for VANET. In his paper the performances of routing protocols are evaluated for different mobility modules and showed the effects of mobility on the efficiency of the routing protocol. In[9] Omar et al proposed an intersection UAV-assisted routing protocol and evaluated it is performances in city scenario against the scalability of vehicles. An Ant-Colony routing optimization is presented in[10] to enhance the performances of a routing mechanism for inter-vehicles communication, this mechanism is evaluated in rural and urban VANET scenarios. The evaluation of routing protocol performances in VANET is widely addressed in the literature against different network parameters. However, the impacts of the routing parameters on the network performances are yet to be considered.

The proposed method in this paper is motivated by the work in[11,12]. Bandi et al[12] defines proposes an offline optimization to fine-tuning the OLSR routing parameters, and solved it with a metaheuristic methods. Jamal et al[11] compares the optimized OLSR with the RFC 3626 set of parameters. Through its work it can be concluded that, Optimizing OLSR protocol parameters set improves the overall network performances. It is also worth to highlight that, their work considers a single VANET scenario. Thus, the work in this paper considers two different VANET scenarios city and highway. Furthermore, the proposed method in this paper is based on a design of experiment based optimization method, which opens the opportunity for adding optimization mechanism to the routing protocols mechanisms.

The rest of the paper is organized as follow: the next section describes the proposed method. Section 3 presents the experimental results and their discussion and section 4 concludes this work.

2. Taguchi Method

Taguchi optimization method is firstly introduced by Genichi Taguchi[13] for minimizing the production cost and increasing profit in manufacturing systems. This method utilizes a systematic approach of experiments design combined with statistical methods to measure the impact of the system inputs on its output.

Taguchi optimization method consists of three phases: planning, experimental design and analysis. The planning phase involves problem definition and optimization targets identification. The experimental phase emphasis on the design of experiments with the Orthogonal Array (OA) method. The analysis phase in Taguchi involves delta analysis and optimization. This work utilizes the delta analysis in the Taguchi analysis part to measure the effect of the GPSR inner parameters, and further uses the optimization steps to find a solution for the optimization problem.

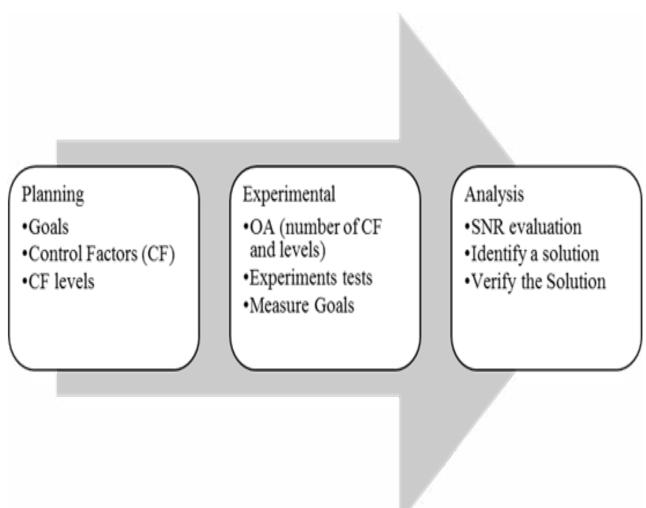

Figure 1. Taguchi method processes follow.

Planning phase: The system understudy is described as VANET city and highway scenarios affected by the

GPSR parameters in terms of delay and PDR. Accordingly two problems are formulated as follow: Find the optimum solution (values) of the GPSR routing parameters that contributes to: 1- Highest PDR, 2- Minimum delay; for 1- city scenario 2- highway scenario. The problem parameters are divided into Control Factors (CF) and outputs. Here the CF is (*Maxjitter, NeighborValidityTime, Beacon Interval*), and outputs are: delay and PDR.

Experimental phase: Taguchi method considers a set of experiments for testing the effect of CF on the outputs. The experiments are conducted based-on the OA method. OA is a predefined set of experiments based on the number of factors and their levels. For example, to obtain the effect of three CF on the output and each factor is given three levels for testing then the OA ($L_9 3^3$) can be used. In this work, three levels (High, Medium and Low) of testing are selected for a control factor. Table 1 presents the OA set of experiments with their corresponding control factor levels. Further, each set of experiment will be repeated with different random seed for both highway and city scenarios. The obtained results of OA set of experiments latter are used for the analysis phase.

Analysis phase: Taguchi method achieves the optimum solution by applying an objective function. Taguchi defines different objective function for minimizing (smaller-the-better), maximizing (larger-the-better) or normalizing (nominal-the-best) a target output. Each objective function is calculated based-on Signal-to-Noise Ratio (SNR) measure. SNR is the ratio between profit and loss of the achieved target for certain experiment. To optimize the delay the SNR is calculated with smaller-the-better (1), and for PDR larger-the-better (2) is used.

Table 1. Orthogonal array table (all values are in seconds)

No	Beacon	Jitter	N.Validity Time
1	2	0.1	20
2	2	0.5	30
3	2	1	40
4	10	0.1	30
5	10	0.5	40
6	10	1	20
7	20	0.1	40
8	20	0.5	20
9	20	1	30

$$SNR_{smaller\_the\_better} = -10 \times \log \sum \frac{Y^2}{n} \tag{1}$$

$$SNR_{larger\_the\_better} = -10 \times \log \sum \frac{1/Y^2}{n} \tag{2}$$

SNR values are used for delta analysis and optimization. Delta analysis is concerned by measuring the effects of the CF on the output. Further, the optimum solution is obtained by comparing between the averages SNR for each control factor levels.

Delta analysis: In this step, the average value of the obtained SNR is calculated for all factors to a specific level. For example: MaxJitter is tested for three levels (high, medium and low). The effect of low level is measured from the observations where the value of the MaxJitter is low (1, 4 and 7 of the OA table). Then, the average SNR of these observations is evaluated. And the impact of the MaxJitter is obtained as the different between the highest and lowest average SNR. Figure 2 represents the obtained delta SNR. Lastly, factors are arranged according to delta value, and this is interpreted as the measure of factors impact on the target output.

	PDR					Delay			
	Level	Beacon	MaxJitter	N.Validity Time		Level	Beacon	MaxJitter	N.Validity Time
City	1	-0.00758	-1.31681	-4.01339	City	1	27.548	21.217	15.099
	2	-0.957593	-3.41139	-1.31681		2	18.444	17.161	20.977
	3	-6.03736	-2.27467	-1.67267		3	8.387	16.001	18.304
	Delta	6.02978	2.09458	2.69659		Delta	19.161	5.216	5.878
	Rank	1	3	2		Rank	1	3	2
Highway	1	-3.703	-4.239	-4.401	Highway	1	53.21	51.65	49.77
	2	-2.817	-4.526	-4.440		2	53.03	49.67	51.02
	3	-5.774	-3.530	-3.453		3	48.47	53.40	53.92
	Delta	2.957	0.996	0.987		Delta	4.75	3.74	4.15
	Rank	1	2	3		Rank	1	3	2

Figure 2. Delta analysis of the SNR value for PDR and delay in city and highway scenarios.

3. Results and Discussion

In this paper, the effects of three routing parameters of GPSR protocol on two VANET scenarios are evaluated. The realistic VANET scenario of Changlun City[14] is modeled with OMNET++ and INET3.5 simulation tools. The VANET protocol stack in the OMNET++ simulator and INET3.5 framework is used for the simulation purposes. Table 2 depicts the simulation parameters. The results presented in this paper are mapped to three goals. The first goal is to show the effect of routing parameters in VANET performances and the influences of different scenarios in their tuned values. The second goal is to quantify the effect of these parameters in the network performances. Lastly, to present the improvements in the network performances by applying the optimum solution evaluated by Taguchi method.

Table 2. Simulation scenarios parameters

Attribute	City	Highway
Dimension	500 x 500 m^2	2000 x 80 m^2
Simulation Time	300s	300s
Number of OBU	30	50
Number of RSU	8	12
Transport Layer	UDP	UDP
Traffic Generation Module	Burst application	Burst application
MAC	IEEE802.11p	IEEE802.11p

Figure 3, Figure 4 and Figure 5 present the effects of different *Neighbor_Validity_Times* (NVT), *Beacon_Intervals (BI)* and *MaxJitters (MJ)* on PDR and delay for city and highway. NVT and BI observations on delay and PDR showed that longer NVT time is preferred than shorter for improving the performances in city and highway. While BI is preferred shorter. The effects of changing NVT and BI intervals in city is higher than in the highway scenarios. The MJ observations showed contradictory in its preferred value between city and highway. The preferred MJ for PDR is high in city and low in highway, while for delay it is preferred high in highway and low in city.

The results of Taguchi Delta analysis are presented in Table 1. The rank value represents the impact of a CF in comparison to other factors, and the highest observed SNR for a CF determines the preferred level to improve the output. For example, BI ranked number 1 for all scenarios, which shows that BI impact in increasing the PDR and reducing delay is higher than NVT and MJ. And the preferred value of BI to reduce the delay in highway is at level 1; as it has the highest SNR value. Taguchi observations showed that the preferred values for NVT, BI and MJ are similar to those obtained by the iterative comparisons in Figure 3, Figure 4 and Figure 5. This concluded that Taguchi method can be used to optimize the routing parameters.

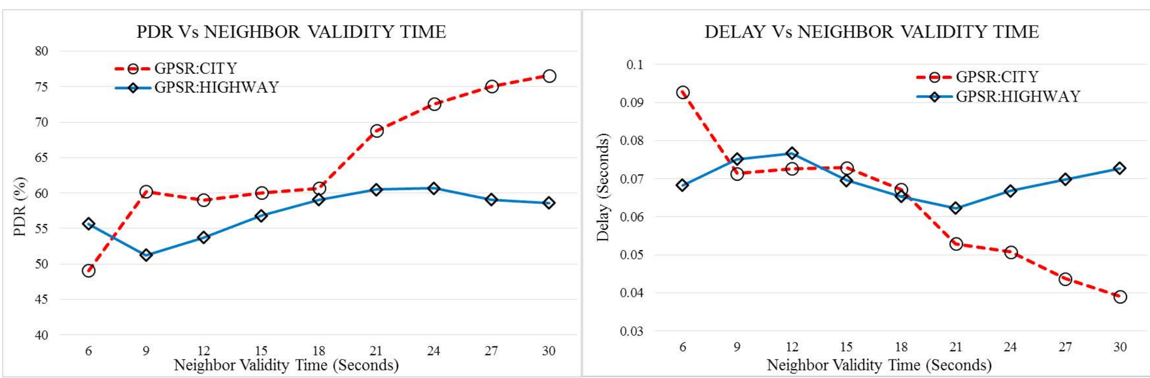

Figure 3. The effects of NVT on PDR and delay for city and highway scenarios.

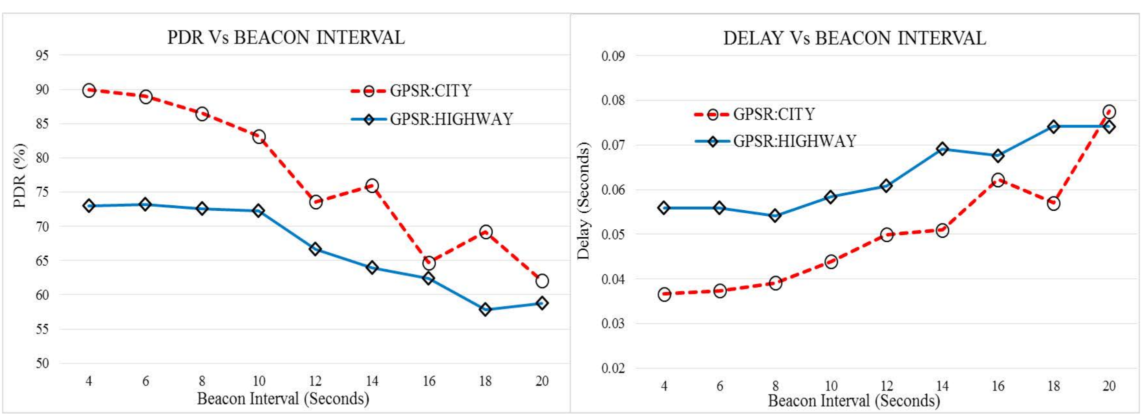

Figure 4. The effects of BI on PDR and delay for city and highway scenarios.

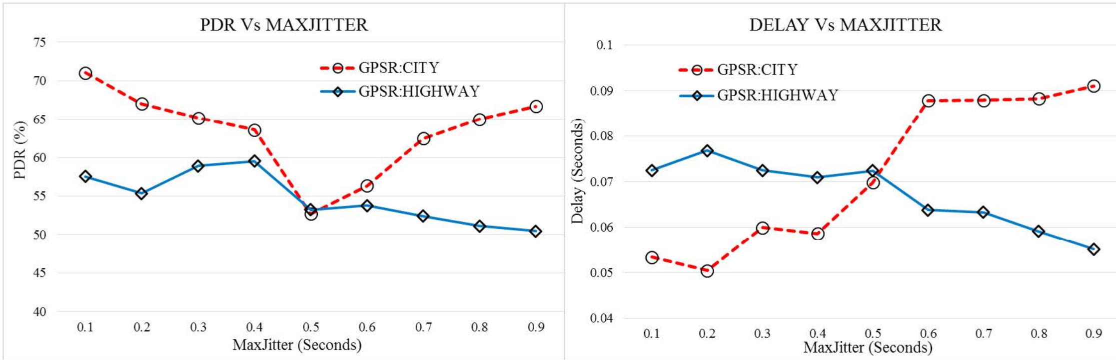

Figure 5. The effects of MJ on PDR and delay for city and highway scenarios.

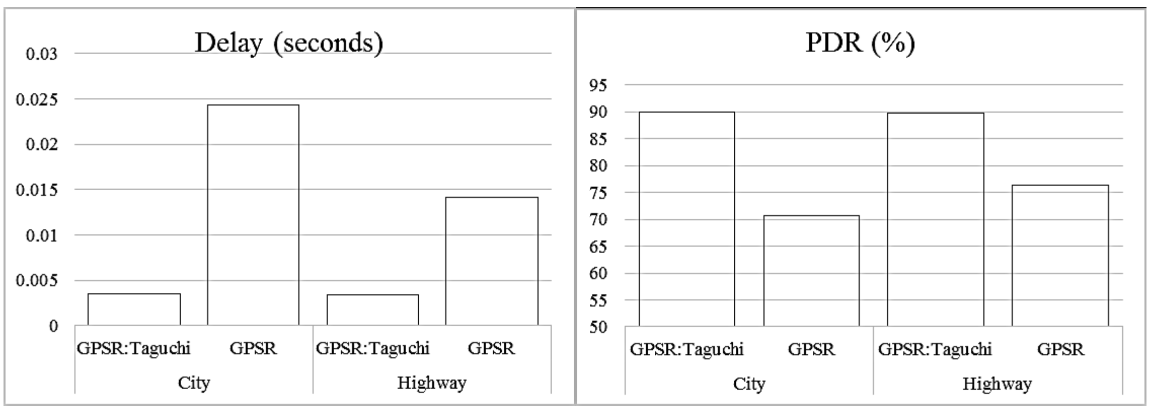

Figure 6. The average delay and PDR observations of Taguchi and GPSR defaults parameters in city and highway for different traffic generations.

The NVT is used by GPSR to keep route information in its table; hence reducing NVT increases the frequent of deleting route information from the table, and required the protocol for initiating the route discovery mechanism more frequently. This results in inducing unnecessary protocol overhead in a network with less topology changes. While its desired for high topological change scenarios. Hence, the preferred value for NVT is optimized with high. The BI is utilized by GPSR for topology information dissemination and data forwarding. Consequently, keeping this value low is preferred for more data forwarding. The MJ is used by a routing protocols to induce a random gap between consequent periodic packets. Increasing this value reduces the probability of collision and increases the delay. Accordingly, in highway scenarios vehicles communication ranges are a part from each other's. Thus the probability of collision is less than in city, where vehicles communication ranges are tends to overlaps. This explains the contradiction in the preferred value of MJ between city and highway.

The observed effects of routing parameters in delay and PDR are directly affected by the network scenario. Thus, to improve the efficiency of a routing protocol, these values should be optimized with respect to the network scenario. The preferred values of GPSR routing parameters obtained by Taguchi method are similar to those evaluated in the iterative comparison. Consequently, the obtained optimum solution is compared with the default values of the GPSR parameters for different traffic generations, and the obtained results are presented in Figure 6. This results showed that, Taguchi optimum solution improved the PDR in city by 20% and 15% in highway. While delay is decreased by 0.02 seconds in city and 0.01 seconds in highway.

4. Conclusion

This paper presents Taguchi optimizationmethod for measuring the effects of GPSR routing parameters on the performances of VANET. The impacts of GPSR routing parameters are evaluated for delay and PDR with two evaluation methods: iterative and Taguchi. The obtained results of both methods showed the same preferred values of the routing parameters to improve the network performances. The evaluation observations highlights the impacts of network scenarios on setting the values of a routing protocol. Accordingly, an optimization mechanism is necessary for setting these values to improve the routing protocol efficiency. Hence, this paper presents an offline optimization of the GPSR routing parameters in highway and city VANET scenarios. The optimum solutions are evaluated in a realistic simulation model of Changlun city. The obtained results showed that, GPSR with Taguchi optimization increases the PDR by 20% in city and 15% in highway. It is also reduces the delay by 0.02 seconds in city and 0.01 seconds in highway.

Taguchi optimization procedure required less number of testing experiments than the iterative method, and its systematic way of measuring the impact of the routing parameters, make it a good candidate for integration with the routing mechanism in a future work.

5. References

1. Karp B, Kung HT. Greedy Perimeter Stateless Routing (GPSR) for wireless networks. In the Proceedings of the Association for Computing Machinery (ACM) 6th Annual International Conference on Mobile Computing and Networking, USA; 2000 Aug 6–11. p. 243–54. Crossref
2. Astorga J, Jacob E, Toledo N, Aguado M, Higuero M. A lossy channel aware parameterisation of a novel security protocol for wireless IP-enabled sensors. Wireless Networks, Springer. 2015 May; 21(4):1289–308. Crossref.
3. Friginal J, de Andres D, Ruiz JC, Gil P. Resilience-driven parameterisation of ad hoc routing protocols: olsrd as a case study. In the Proceeding of the Institute of Electrical and Electronics Engineers (IEEE) 30th International Symposium on Reliable Distributed Systems, Madrid, Spain; 2011 Oct 4–7. p. 85–90. Crossref.
4. Gomez C, Garcia D, Paradells J. Improving performance of a real ad-hoc network by tuning OLSR parameters. In the Proceeding of the 10th Institute of Electrical and Electronics Engineers (IEEE) Symposium on Computers and Communications (ISCC'05), Murcia, Spain; 2005 Jun 27–30. p. 16–21. Crossref.
5. Toutouh J, Garcia-Nieto J, Alba E. Intelligent OLSR routing protocol optimization for VANETs. Institute of Electrical and Electronics Engineers (IEEE) Transactions on Vehicular Technology. 2012 May; 61(4):1884–94. Crossref.
6. Bala R, Krishna CR. Scenario based performance analysis of AODV and GPSR routing protocols in a VANET. In the Proceeding of the Institute of Electrical and Electronics Engineers (IEEE) International Conference on Computational Intelligence and Communication Technology (CICT), Ghaziabad, India; 2015 Feb 13–14. p. 432–7. Crossref.
7. Hamid B, Mokhtar ENE. Performance analysis of the Vehicular Ad hoc Networks (VANET) routing protocols AODV, DSDV and OLSR. In the Proceeding of the Institute of Electrical and Electronics Engineers (IEEE) 5th International Conference on Information and Communication Technology and Accessibility (ICTA), Marrakech, Morocco; 2015 Dec 21–23. p. 1–6.
8. Venkatesh, Indra A, Murali R. Routing protocols for Vehicular Adhoc Networks (VANETs): a review. Journal of Emerging Trends in Computing and Information Sciences. 2014 Jan; 5(1):25–43.
9. Oubbati OS, Lakas A, Lagraa N, Yagoubi MB. UVAR: An intersection UAV-Assisted VANET routing protocol. In the Proceeding of the Institute of Electrical and Electronics Engineers (IEEE) Wireless Communications and Networking Conference, Doha, Qatar; 2016 Apr 3–6. p. 1–6.
10. Majumdar S, Shivashankar, Prasad PR, Kumar SS, Kumar KNS. An efficient routing algorithm based on ant colony optimisation for VANETs. In the Proceeding of the Institute of Electrical and Electronics Engineers (IEEE) International Conference on Recent Trends in Electronics, Information & Communication Technology (RTEICT), Bangalore, India; 2016 May 20–21. p. 436–40.
11. Toutouh J, Garcia-Nieto J, Alba E. Intelligent OLSR routing protocol optimization for VANETs. Institute of Electrical and Electronics Engineers (IEEE) Transactions on Vehicular Technology. 2012 May; 61(4):1884–94. Crossref.
12. Bandi A, Chandrasekhar BN. Parameters tuning of OLSR routing protocol with metaheuristic algorithm for VANET. In the Proceeding of the Institute of Electrical and Electronics Engineers (IEEE) International Advance Computing Conference (IACC), Bangalore, India; 2015 Jun 12–13. p. 1207–12. Crossref.
13. Peace GS. Taguchi methods: a hands-on approach. Addison Wesley; 1993. p. 522.
14. Changlun [Internet]. 2016 [updated 2017 Oct 9; cited 2016 Mar 16]. Available from: https://en.wikipedia.org/wiki/Changlun