CHEMICAL ENGINEERING TRANSACTIONS
VOL. 46, 2015
A publication of AIDIC
The Italian Association of Chemical Engineering
Online at www. aidic. it/cet
Guest Editors: Peiyu Ren, Yanchang Li, Huiping Song

ISBN 978-88-95608-37-2; **ISSN** 2283-9216
DOI: 10.3303/CET1546105

Research on Carbon Distribution in a Scenic Area Based on the Theory of Quality Control

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With quality control theory, this paper has designed four kinds of control charts which were jointly used to effectively control the carbon loads of a scenic area and guide tourist shunting. In this way, the equilibrium distribution of carbon dioxide in a scenic area could be realized, and the carbon loaded area could be controlled and stopped to do any more damages to the ecological environment to the whole scenic area which would better facilitate the sustainable development of it. Lastly, this paper took Jiuzhai Valley as an example to set up a conception model. A simulation was done with SIMULINK of MATLAB software to verify the effectiveness of quality control chart in controlling carbon distribution of a scenic area.

1. Introduction

Tourism grows rapidly but the over-exploitation of scenic areas has already given rise to all kinds of negative effects. Zou(2004) reported that tourism is now bringing more pressure to ecological environment so that a threat is posed to the sustainable development of the scenic area. Qiu(Ge and Ren(2010))said how to cope with the contradiction between the increasing tourist demands and ecological environment has become an urgent issue for the scenic area. This contradiction, in essence, comes down to the disequilibrium carbon distribution in the scenic area. Tourist number keeps expanding especially in peak seasons, as a result, the total carbon emission in the scenic area soars, disequilibrium exacerbates, carbon in scenic spots overloads, the environment of the scenic area degrades and sustainable development gets into trouble. Carbon distribution control in the scenic area is an effective way to realize its sustainability. Moreover, carbon distribution equilibrium control can lead to a balanced tourist distribution and ease the overload pressure of scenic spots.

2. Proposal of the issue and relevant theories

Low-carbon economy comes hand in hand with the arrival of the 21st century. Global ecological environmental problems are becoming more and more serious, thus new demands are put forward for the development of tourism as well as the transformation of economic growth model. Cai (2010) said that low-carbon tourism is a new travel model echoes with low-carbon economy, and it is playing a bigger role in China’s tourism development. The growth of natural scenic area is more connected with low-carbon pattern than ever before. As Xiao (2012) and Ge(2013) reported ,traditional methods such as simply control tourist density can no longer meet the needs of some high-demanding scenic areas. Therefore, it is necessary to control per unit carbon density to protect natural and human landscapes. A monitoring control chart on carbon distribution of a natural scenic area can be set up on the basis of quality control chart principle, and thanks to the maturing technology, As zou(2006) said, the precision of the monitoring method as well as the equipment both improved greatly. Therefore, carbon dioxide density can be taken as a monitoring indicator to judge the real carbon load of the scenic area.

Considering that the variable carbon sources of a scenic area are tourists and the entered sightseeing vehicles, and the increment of carbon density is in positive linear relation with the increment of tourist number, it is fair to take the density of carbon dioxide as a monitoring indicator. By monitoring carbon density, tourist density can also be reflected. In other words, carbon load indicates tourist density. By shunting tourists at the very beginning or direct them to other scenic spots, namely pre-scheduling, a balanced tourist distribution is

Please cite this article as: Zhou Z., Jin M.Z., Zhao R., 2015, Research on carbon ddistribution in a scenic area based on the theory of quality control, Chemical Engineering Transactions, 46, 625-630 DOI:10.3303/CET1546105

possible as well as carbon distribution equilibrium. Ultimately, He (2003) reported that the goal of preserving the natural scenic area and improve tourists' satisfaction can be achieved. Ji(2001) also repoted when tourist number exceeds or comes close to the largest capacity of a scenic spot, the whole scenic area will be damaged at a faster pace, and calcification of water and soil, vegetation destruction, acidification of waters and other problems will arise. Therefore, an equilibrium control of carbon distribution in the scenic area is conducive to the preservation of natural ecological environment as well as the sustainable development of the scenic area.

Control chart includes attribute control chart and variable control chart, both of which need to measure and test a specific quality feature in the first place. Wang (2002) said, by evaluating these control charts, it is possible to evaluate the historic state, present state of the process. Moreover, with accumulated experiences and experts' opinions, the short-term future state of the process can also be predicted.

It is found out through research that in controlling carbon distribution of a scenic area, control chart and x-S control chart are the most appropriate.

3. The design of carbon distribution control chart in a scenic area

If the scenic spot number is n, then m (m≤n(n-1)/2) sides will constitute a control chart shown in Fig. 1.:

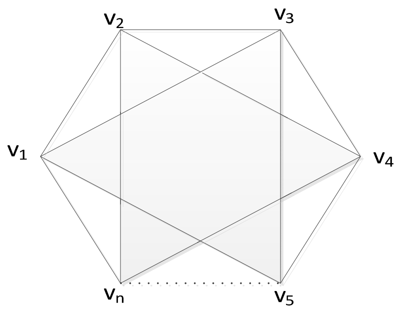


Figure 1: The scenic area concept map

Supposing that V=$\{v_1,v_2,\ldots,v_n\}$ is the set of all scenic spots in the scenic area, the CO_2 emission of each scenic spot comes from the breath of tourists, local residence and working staffs, as well as the emission of sightseeing vehicles, and so on. Record the CO_2 emission amount of each scenic spot at different hours as $M(t)=\{m_1(t),\ m_2(t),\ldots,m_n(t)\}$. Tourist number of each scenic spot at different hours is recorded as $X(t)=\{x_1(t),x_2(t),\ldots,x_m(t)\}$, and CO_2 emission coefficient of each scenic spot is $K=\{k_1,k_2,\ldots,k_n\}$, then (Eq. 1) can be written.

mi(t) = kixi(t) i = 1,2,….,n. (1)

Rao(2012)said the CO_2 of each scenic spot is mainly absorbed by vegetation such as trees and herbals. The absorption ability of the vegetation is $C=\{c_1,c_2,\ldots, cn\}$. According to each scenic spot's per unit CO_2 emission $M(t)=\{m_1(t),m_2(t),\ldots,m_n(t)\}$ and the vegetation's per interval absorption ability $C=\{c_1,c_2,\ldots,c_n\}$, it can be obtained that the load rate of CO_2 in each scenic spot $LR=\{lr_1,lr_2,\ldots,lr_n\}$, according to (Eq. 2).

lri(t) = mi(t)/ci, i = 1, 2, …, n. 2)

Each scenic spot's CO_2 load rate is directly connected with its sustainable development. Control chart is adopted to control the CO_2 load rate of each scenic spot to ensure that the load rate is developed in a balanced way when it is under control.

Sample the current carbon density of each scenic spot from 8:30 a.m. and observe them every five minutes. By calculating the samples, the carbon load rate *c/C* can be obtained. The range and average value of n scenic spots at each time nodes for the convenience of future calculation.

Table1. Data sampling table

Observing times	time	carbon load rate of the scenic area(c/C）				range	average value
		Scenic spot 1	2	3	…		
1	8.30						
2	8.35						
3	8.40						
4	...						
6	16:00						

3.1 Control chart of CO2 load rate for the scenic area

There are n scenic spots in the area, then CO2 load rate of scenic spot i is recorded as lri(t). As lri(t)≤1, the UCL of the quality control chart is 1-ξi. The control chart of CO2 load rate for scenic spot i is shown as Fig. 2.

In Fig. 2, $lr_i(t)$ changes constantly with time: when $t=t_1$, $lr_i(t)=UCL(t)$. Then it is necessary to control the CO_2 load rate of scenic spot i by slowing down the upstream nodes' inflow or speed up the inflow to downstream nodes.

3.2 Control chart of CO_2 load rate for the scenic area

If the CO2 load rate of each scenic spot is lri(t), then the CO2 emission at the moment t is mi(t), and the CO2 absorption volume of each scenic spot is ci. As a result, the CO2 loading rate of the scenic area is given by (Eq. 3).

$$lr^{(t)}= \frac{\sum_{i=1}^{n} m_i(t)}{\sum_{i=1}^{n} c_i} \dots \qquad (3)$$

Similarly, setting the control upper limit UCL at 1-ξ, then the CO2 loading rate of the scenic area is given by Fig. 3.
In Fig. 3, when 0<t<t1, there is no need to control the CO2 loading rate when it is below the control limit; when t1<t<t2, and the CO2 loading rate is beyond the control limit UCL, then the number of tourists and entering vehicles should be controlled to lower it.

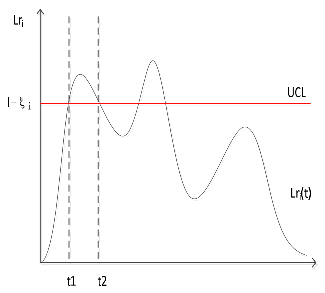


Figure 2: CO2 rate control chart of No. i scenic spot

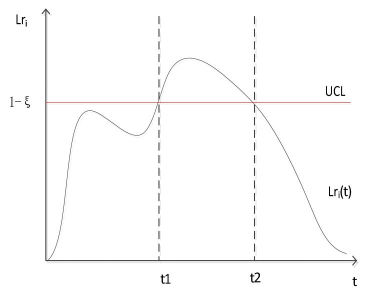


Figure 3: The total rate control chart

3.3 *Absolute control chart* $\overline{x}(t)+3\delta(t)$ *and relative control chart* $\overline{x}(t)+3\delta(t)$

If the CO2 load rate of each scenic spot is lri(t), then CO2 load rate of the scenic area is given by Eq. (4).

$$\overline{x}(t) = lr^{(t)} = \frac{\sum_{i=1}^{n} m_i(t)}{\sum_{i=1}^{n} c_i} \tag{4}$$

$$\delta(t) = \sqrt{\frac{1}{n}\sum_{i=1}^{n}\left(lr_i(t) - lr(t)\right)^2} \tag{5}$$

Meanwhile, the CO2 load rate of each scenic spot at moment t can be represented by its standard deviation δ(t) (Eq. 5).
In this case, the central line of control chart $\overline{x}(t)+3\delta(t)$ can be set up and recorded as $\overline{x}(t)$ (Fig. 4). The upper control limit is $\overline{x}(t)+3\delta(t)$.
The load rate of a scenic spot can well reflect the loading condition of the scenic spot, and the load rate of a scenic area can reflect the whole scenic area's loading condition. The relative control chart is shown as follows $\overline{x}(t) + 3\delta(t)$: set UCL(t)=3δ(t). The relative control chart is constituted on the basis of difference value between scenic spot load rate and scenic area load rate.
In Fig. 5, when $0<t<t_1$, the load rate of scenic spot *i* is bigger than that of the scenic area, but smaller than *UCL(t),* therefore there is no need to control it; when $t_1<t<t_2$, the CO_2 emission of scenic spot *i* can be lowered by limiting the tourist flow of the upstream nodes and accelerating tourist flow to other downstream nodes.

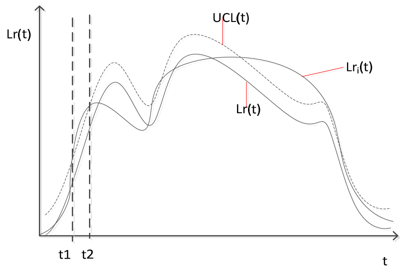


Figure 4: $\overline{x}$ *(t)+3δ(t) 4 absolute control chart*

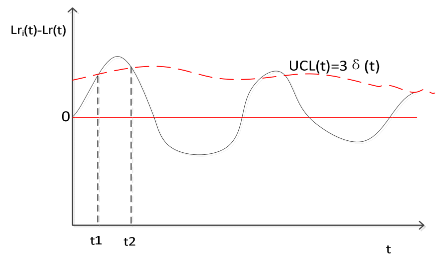


Figure 5: Relative control chart $\overline{x}(t)+3\delta(t)$

On the basis of the above four kinds of control charts, a scenic area can adopt the combination of Figs. 2-4, or the combination of Figs. 2, 3 and 5 to control its CO2 load rate. In the following chapters, simulation is used to explain the operation mechanism of the control charts.

4. Model establishment and simulation

Simulink module of software Matlab is used to conduct the simulation. The source data is the real data of Jiuzhai Valley on 30th July, 2012. Four stimulation models were set up for four scenic spots, and by running the four control charts, the dynamic changes of the carbon distribution in the scenic area could be reflected in real time.
Suppose the scenic area has four scenic spots. Fig. 6 is a virtual scenic area which consists of an entrance, an exit and four scenic spots A, B, C and D. The conceptual model of the scenic spot is as shown in Fig. 6.

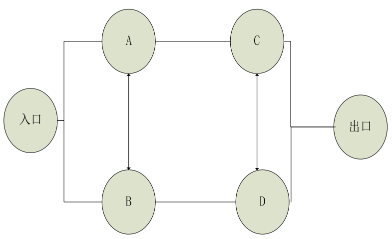


Figure 6: The conceptual model of the scenic spot

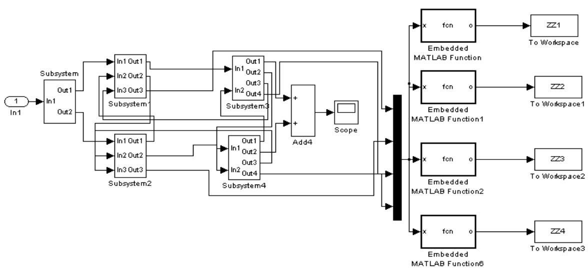
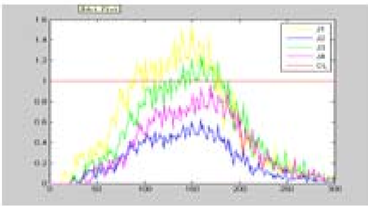
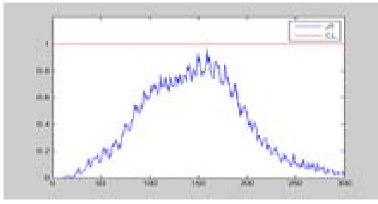


Figure 7: The simulation model diagram of Simulink

The modules for entrance, scenic spot A, B, C, D and the exit are Subsystem, Subsystem 1, Subsystem 2, Subsystem 3, Subsystem 4 and add4 respectively. The following function module is the data process of the four control charts (Fig. 8).



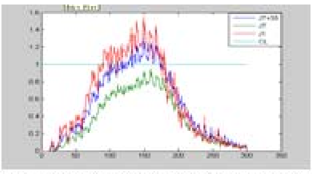
(a) Control chart of the current load rate



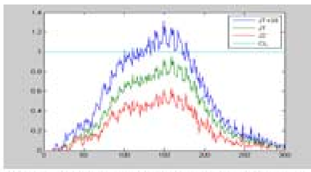
(b) Control chart of the total load rate of the scenic area of scenic spots

Figure 8: The scenic spots in the current load rate control diagram and the total load rate control chart

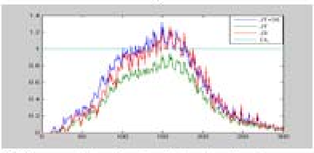
In Fig. 8(a), the yellow line J1 represents the load rate of scenic spot 1, the blue line is for scenic spot 2, while green line for scenic spot 3 and purple for scenic spot 4. The red line refers to the control limit, namely when ci=Ci. In Fig. 8b, the blue line represents the total load rate of the scenic area. Judging from Fig. 8, the carbon distribution in scenic 1 and 3 needs to be adjusted. JT refers to the total load rate of the scenic spot, JT+3δ refers to the upper control limit of the scenic area, and CL refers to the control limit of full load rate. For example in Fig.9 (a), scenic spot 1 is full loaded at the beginning and no proper tourist shunting is carried out. Whereas in Fig.9(c), the load of scenic spot 3 is lower than that of the scenic area on the whole, however, its peak time surpassed the largest load so that a pre-shunting or a post- guidance is needed.



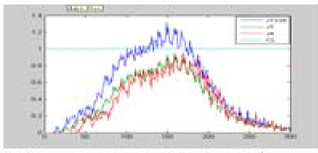
(a) $\bar{x}(t)+3\delta(t)$ control chart of load rate in scenic spot A



(b) $\bar{x}(t)+3\delta(t)$ control chart of load rate in scenic spot B

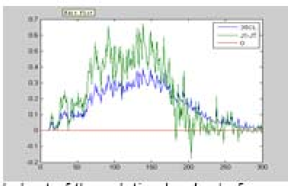


(c) $\bar{x}(t)+3\delta(t)$ control chart of load rate in scenic spot C

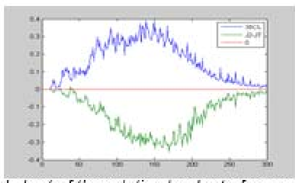


(d) $\bar{x}(t)+3\delta(t)$ control chart of load rate in scenic spot D

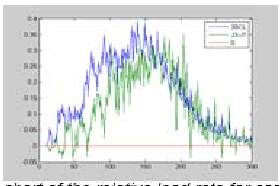
Figure 9: The scenic spots in load rate and the load and full load control limit diagram of the scenic spot



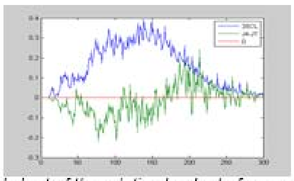
(a) control chart of the relative load rate for scenic spot A



(b) control chart of the relative load rate for scenic spot B



(c) control chart of the relative load rate for scenic spot C



(d) control chart of the relative load rate for scenic spot D

Figure 10: The control charts of the relative load rate for each scenic spot

The blue line is the 3δcontrol limit of relative load rate; the green line represents the load rate value gap between scenic spot and scenic area, and the red line is the control limit when the load rate of the scenic spot equals to that of the scenic area.

5. Conclusions

By expanding the theory of quality control and combining the four carbon distribution control charts which are set up on the basis of the real development conditions of the scenic spot, it turns out that control chart is effective in shunting tourists in rush hours. The control chart is efficient and flexible, and its monitoring system is easy to operate. Therefore, the control chart is conducive to the sustainable development of the scenic area. Moreover, quality-control-based carbon distribution control research is a relatively new perspective and the whole simulation model runs well which well illustrates that it is feasible to apply quality control chart to scenic areasl.

Acknowledgements

This research was supported by the Major International Joint Research Program of the National Natural Science Foundation of China (No. 71020107027), the National Natural Science Foundation of China (No. 71001075), and Central University Fund of Sichuan University (No.skqy 201112).

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