Evaluation of a railway telecommunication network

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Abstract

This paper considers the evaluation of the railway telecommunication network from the users point of view by presenting an example of the application of the method for the evaluation of the current situation. The problems of questionnaire design for the collection of information from users are discussed. Multidimensional scaling and factor analysis are considered along with the actual application in the telephone telecommunication network of Belorussian Railways. This concept can be used in decision support systems in order to provide managers of railway telecommunication networks of the countries of the former USSR with the comprehensive analysis of the current status of telecommunication networks.

1 Introduction

The most of the railway companies run internal telecommunication networks, which provide a range of services. For example, the state railway company of the Republic of Belarus (Belorussian Railways) like any railway company in the former USSR runs its own telephone, telex and data transmission networks which cover a territory of about 200,000 sq.km. One of the main features of all railway telecommunication networks in the former USSR at the moment is fast evolution from networks which combine all kinds of equipment (some installed
in the post-war years) toward modern digital telecommunication networks. Therefore the problems concerning the replacement of the obsolete telecommunication equipment and the reconfiguration of networks arise very often.

In order to solve these problems railway telecommunication managers have to make value judgements on issues that have not been encountered before and may be nonrecurring. Such decisions must be based on comprehensive information including the detailed analysis of the current situation within the telecommunication networks.

Today, it is practically impossible to analyse of the situation on every part of the railway telecommunication networks of the former USSR by technical means alone, because of the lack of proper measurement facilities and the restrictions of old-fashioned telecommunication equipment being used. In these conditions additional information concerning the current situation on networks can be obtained from the users of railway telecommunication services.

The main purpose of this paper is to elaborate the evaluation of the current situation within the railway telecommunication network from the users point of view as well as presenting a method of collecting and analysing information from users which will allow telecommunication managers to find out the areas of the network which have the poorest quality of services and the underlying reasons.

Both the concept and the method of this research is of great importance at the moment for all the telecommunication administrations of the railways of the countries of the former USSR because of the changes in all spheres of life caused by rapid transition towards a market-oriented economy. This approach is unprecedented on any railway telecommunication network of the former USSR.

2 The concept of evaluation of the current situation on railway telecommunication networks from the users’ point of view

The main idea of the concept evaluating the current situation on the railway telecommunication network from the users’ point of view is as follows. There are thousands of telecommunication service users on railways. Each of them makes use of some services and is able to evaluate the current situation on the telecommunication network based on his or her own experience. Having elicited information from as many such users as possible and processed the data by special procedures, telecommunication managers are able to evaluate the current situation on the network from the users’ point of view.

This idea is not new for the railway telecommunication managers in the former USSR. In fact they have already applied a similar idea. Usually one or two managers are responsible for making the decisions concerning the development of telecommunication networks on each railway of the former USSR. One of their tasks is to collect the information about the current situation on networks as a whole. Their usual way of getting information is formal and
informal talks to people dealing with networks (users, operating personnel, etc.). However, often the information does not reflect the real situation due to the lack of time for collection and analysis, conflicting opinions of operation personnel, management ignorance of analysis techniques, etc. Sometimes this problem impairs correct decision-making.

In order to improve the quality of decision-making processes in the field of the telecommunication networks on the railways of the former USSR, it is necessary to implement a specialized computer-based method for evaluation of users’ opinions concerning the situation on the network instead of one being in use.

Techniques for solving similar tasks (for example the methods of marketing research) have been used in Western Europe and America for a long time and there is a large volume of literature describing these techniques [1]. Therefore one way of getting and analysing the information from the users of telecommunication networks implies an application of the traditional methods of dealing with similar problems adjusted to this specific case.

3 A method of the realisation of the concept

Usually, telecommunication managers are interested in various aspects of the situation of the network (traffic on routes, the quality of the services, etc.). Therefore, theoretically, there are a lot of ways of realising the suggested concept (each way depends on the issue that is studied). For each case, a method of realisation of the concept should be elaborated individually.

One method comes from the main duty of telecommunication managers in the railways of the former USSR which is a search for the "weak" parts of the networks and the underlying reasons for weaknesses. In order to facilitate solving this task the following steps should be done according to the concept described above:

1. Interviewing of users at network telecommunications nodes in order to find out a set of nodes where the quality of service is unsatisfactory;
2. Conducting a special survey at each "unsatisfactory" node in order to find out the reasons causing the situation.

In order to get the relevant data from users a railway telecommunication administration should conduct some surveys using a structured questionnaire. The best way of getting data from users is to question them directly. This may be done by telephone, mail or in person. In the countries of the former USSR the procedures of questioning are rather new and this peculiarity must be taken into consideration. Before the design of the questionnaire starts, it is necessary to know exactly what information should be collected (for example, about the situation of the whole network or about the situation of the particular area).

The experience gained during the test of the different kinds of questionnaires shows that there are two main problems in the questionnaire design for the
evaluation of the railway telecommunication networks in the former USSR: the type of questions and the type of scales which should be used in a questionnaire.

Individual questions should make the user's task of answering as simple as possible. In general two forms of individual questions can be used in questionnaires. A close-ended question provides respondents with a list of the possible answers. An open-ended question, instead of the list of possible answers, allows respondents to answer in their own words. Each type of question has advantages and disadvantages.

A cultural legacy of the former USSR is that users are often unwilling or have lack of time to answer open-ended questions. Therefore, we have only used closed questions formulated in accordance with the Likert scale [1]. This minimises the collection of superfluous data and consequently the loss of time for users.

4 Example of the evaluation of current situation of the railway telecommunication network

To date the scale of load and passenger transportation between the countries of the former USSR and Europe has steadily increased. Currently these activities are carried out by the traditional means of transport (by rail, road or sea). Their speed, however, does not satisfy most of customers in Europe and the countries of the former USSR. One possible solution of improvement of the transport services would be to build a high-speed railway system between the countries of the former USSR and Western Europe. This project is currently examined by the EU.

As Belarus is situated between Russia and Poland, the high-speed railway would have to pass through Belarus. Such involvement would necessitate the revision of all aspects of current situation of the Belorussian Railway, including telecommunications.

The Belorussian Railway runs its own internal telephone network. There are about 150 telephone exchanges and about 30000 telephone users in this network. A half of all telephone exchanges were built more than 15 years ago and the first digital telephone exchanges have just been installed.

For fast evaluation of the current situation on the internal railway telephone network from the users' point of view, the respondents at the main railway stations of Belorussian Railway were asked only one question: "Are you satisfied with the quality of the telephone service as a whole?". Two answers were possible: "Yes" and "No". All interviews were made by phone. Primary data processing showed the percentages of users who were satisfied and unsatisfied with the current quality of service at each station. The best way to present the obtained results is to use bar charts. For instance, the result for telephone service at one railway station on the Belorussian Railway is shown in Figure 1.
The interpretation of the results obtained on each station depends on the person responsible for decision making. In any case, it is possible to make preliminary conclusions concerning the quality of services from the users’ point of view.

![Bar chart](image)

Figure 1. Result of the fast evaluation of telephone services at one station

Secondary data processing allowed to pick out the railway station the research where showed that the quality of the telephone service from the telephone network administrator’s point of view was unsatisfactory. In order to do so, the telephone network administration had set up a maximum percentage (10%) of unsatisfactory answers allowable. Comparing the percentage of the unsatisfactory answers of each station with the maximum which were tolerable, the telephone network administration identified the group of railway stations where a special survey should be conducted in order to reveal the reasons causing the situation.

In the first step of the investigation process of the situations at the "unsatisfactory" stations, special methods of perceptual mapping were applied. These methods are able to produce a graphical representation of how users at the station perceive the quality of telephone service when communicating with users at the other railway stations on different routes and parts of the network. According to this technique, after the data from users questionnaires has been processed a diagram (or a map) is produced in which the routes and the parts of the network perceived by users to be similar are located close together and routes perceived to be dissimilar are located far apart [3]. It is possible to generate diagrams both for an individual user and for groups of users.

The use of these methods is based on the fact that every user possesses some knowledge about the situation on the telecommunication network. He or she is able to compare each pair of network routes, point out the "better", and even evaluate the degree of similarity between them using any criteria.

One of the most popular methods of perceptual mapping is nonmetric multidimensional scaling [3]. This method uses a rank data ordered according
to similarity to generate a perceptual map. Investigating the situation at the "unsatisfactory" stations users were first asked to compare the degree of the similarity of the quality of the telephone services of each pair of available routes. For example the data from the user of an "unsatisfactory" station is shown in Table 1 ("1" in the Table 1 means that the routes are practically similar from the point of view of the user, and "9" - the routes are completely dissimilar).

Table 1. Example of input data from one user

<table>
<thead>
<tr>
<th></th>
<th>Route 2</th>
<th>Route 3</th>
<th>Route 4</th>
<th>Route 5</th>
<th>Route 6</th>
</tr>
</thead>
<tbody>
<tr>
<td>Route 1</td>
<td>9</td>
<td>8</td>
<td>8</td>
<td>9</td>
<td>9</td>
</tr>
<tr>
<td>Route 2</td>
<td>-</td>
<td>2</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Route 3</td>
<td>-</td>
<td>-</td>
<td>2</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Route 4</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Route 5</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>2</td>
</tr>
</tbody>
</table>

Applying a nonmetric multidimensional scaling Kruskal algorithm [3] to these data yielded the two-dimensional map shown in Figure 2.

![Figure 2: Perceptual map of the telephone network routes at one station](image)

Examining the map in Figure 2 we see that Route 1 is located far apart from the others. Approximately the same results were obtained from the most of users at the station. This result causes the necessity for additional investigation why users perceive this route such way. Having done the investigations it was revealed that the traffic on this route was very heavy and the route is overloaded.

In spite of the attractiveness of the methods of nonmetric multidimensional scaling they have some disadvantages. These methods only produce well interpreted perceptual maps when one or two routes strongly differ from the
others. For example a real pattern of the Kruskal algorithm perceptual map at one railway station is shown in Figure 3.

![Perceptual map of telephone network routes]

Figure 3: Typical example of perceptual map of the telephone network routes

In addition to the traditional problem of nonmetric multidimensional scaling, the interpretation of the names of the axes on the map, makes it difficult to draw any conclusions about the quality of routes from the map.

In those cases when the use of traditional methods of nonmetric multidimensional scaling did not lead to the simple interpretation of a produced perceptual map, a specially elaborated method for perceptual mapping of the telephone network was used.

The main idea of the method is as follows. It was noticed that users at every station were able to rank all available routes easily by taking into consideration the total waiting time for getting any available channel (including repeated attempts) on each route and by ranking all available routes according to the quality of the telephone channels on that route. Using this method and getting information regarding the rank of available routes it was possible to make one-dimensional scaling for each route according to the total waiting time or the quality of telephone channels. In order to do one-dimensional scaling one of the first methods of multidimensional scaling was applied [4], which requires that groups of users are questioned regarding the order in which they rank routes. A users' preference matrix may then be produced to calculate the numerical characteristics of each route, based on the Thurstone model of preference.

For example in Table 2 routes are ordered in rank according to total waiting time of users. The users preference matrix was produced (Table 3) using this data and numerical characteristics for each route were calculated (Table 4).
Table 2. Example of rank ordering for some routes from users

<table>
<thead>
<tr>
<th>User</th>
<th>Route 1</th>
<th>Route 2</th>
<th>Route 3</th>
<th>Route 4</th>
<th>Route 5</th>
<th>Route 6</th>
</tr>
</thead>
<tbody>
<tr>
<td>User 1</td>
<td>6</td>
<td>3</td>
<td>2</td>
<td>4</td>
<td>5</td>
<td>1</td>
</tr>
<tr>
<td>User 2</td>
<td>6</td>
<td>5</td>
<td>2</td>
<td>1</td>
<td>4</td>
<td>3</td>
</tr>
<tr>
<td>User 3</td>
<td>5</td>
<td>6</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>User 4</td>
<td>5</td>
<td>6</td>
<td>1</td>
<td>3</td>
<td>2</td>
<td>4</td>
</tr>
<tr>
<td>User 5</td>
<td>6</td>
<td>5</td>
<td>2</td>
<td>4</td>
<td>3</td>
<td>1</td>
</tr>
<tr>
<td>User 6</td>
<td>5</td>
<td>6</td>
<td>3</td>
<td>2</td>
<td>1</td>
<td>4</td>
</tr>
</tbody>
</table>

Table 3. Preference matrix of routes for users

<table>
<thead>
<tr>
<th></th>
<th>Route 1</th>
<th>Route 2</th>
<th>Route 3</th>
<th>Route 4</th>
<th>Route 5</th>
<th>Route 6</th>
</tr>
</thead>
<tbody>
<tr>
<td>Route 1</td>
<td>-</td>
<td>0.50</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
</tr>
<tr>
<td>Route 2</td>
<td>0.50</td>
<td>-</td>
<td>0.00</td>
<td>0.17</td>
<td>0.17</td>
<td>0.00</td>
</tr>
<tr>
<td>Route 3</td>
<td>1.00</td>
<td>0.00</td>
<td>-</td>
<td>0.67</td>
<td>0.83</td>
<td>0.67</td>
</tr>
<tr>
<td>Route 4</td>
<td>1.00</td>
<td>0.83</td>
<td>0.33</td>
<td>-</td>
<td>0.67</td>
<td>0.67</td>
</tr>
<tr>
<td>Route 5</td>
<td>1.00</td>
<td>0.83</td>
<td>0.17</td>
<td>0.33</td>
<td>-</td>
<td>0.50</td>
</tr>
<tr>
<td>Route 6</td>
<td>1.00</td>
<td>1.00</td>
<td>0.33</td>
<td>0.33</td>
<td>0.50</td>
<td>-</td>
</tr>
</tbody>
</table>

Table 4. Numerical characteristics for the routes

<table>
<thead>
<tr>
<th>Coordinate along 'Total waiting time' axis</th>
<th>Route1</th>
<th>Route2</th>
<th>Route3</th>
<th>Route4</th>
<th>Route5</th>
<th>Route6</th>
</tr>
</thead>
<tbody>
<tr>
<td>-1.55</td>
<td>-0.63</td>
<td>0.78</td>
<td>0.62</td>
<td>0.32</td>
<td>0.63</td>
<td></td>
</tr>
</tbody>
</table>

Then considering that the total waiting time and the quality of channels are the names of the axes on the two-dimensional map the results for each route are located on the produced map. In Figure 4 a real example of perceptual map that was produced by the method describe above is shown.
Quality of telephone channels

Good

Route 3

Bad

Total waiting time

Good

Route 4

Route 6

Route 5

Route 2

Route 1

Figure 4: Example of the perceptual map of the telephone network routes

In this case it is clear that Route 1 is probably overloaded and technical characteristics or the maintenance of equipment on Route 2 is not satisfied.

A special survey was conducted to provide a detailed analysis of routes detected by the methods using perceptual mapping. The questionnaire was based on preliminary information from the first series perceptual maps and combined several statements concerning the different aspects of functioning this route (Table 5). Each respondent rated his or her level of agreement with each statement using five-point scale: 5 - strongly agree; 4 - agree; 3 - neutral; 2 - disagree; 1 - strongly disagree.

The analysis of collected data was made in two phases. During the first one standard statistical methods were applied to each statement. This allowed the researchers to gather information concerning each individual statement and therefore to gain a more detailed understanding of the situation on the route.

In the second phase, factor analysis was applied to the whole data set. The main goal of the second phase was to determine the underlying dimensions or factors which cause the problems. It means that, based on how each statement rating correlated with the others, a researcher may group some statements together in order to form factors and thus reveal previously hidden reasons behind the current situation [2].

Applying the traditional method of factor analysis to the collected data it was found out that three factors were responsible for the situation. Table 5 shows
which statement corresponded to each of three factors (sign "*" indicates that the statement is strongly correlated to the factor).

Table 5. Results of factor analysis

<table>
<thead>
<tr>
<th>Statement</th>
<th>Factor1</th>
<th>Factor2</th>
<th>Factor3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Audibility during a conversation with users at Station ... is very bad</td>
<td></td>
<td></td>
<td>*</td>
</tr>
<tr>
<td>It is very difficult to reach users located at Station ... by phone</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>I prefer to phone users at Station ... through an operator</td>
<td>*</td>
<td></td>
<td></td>
</tr>
<tr>
<td>I phone users from Station ... often</td>
<td></td>
<td>*</td>
<td></td>
</tr>
<tr>
<td>I am satisfied with the quality of service on the route to Station ...</td>
<td>*</td>
<td></td>
<td></td>
</tr>
<tr>
<td>There are a lot of additional signals in telephone channels while phoning to users at Station ...</td>
<td></td>
<td>*</td>
<td></td>
</tr>
<tr>
<td>Time from the first attempt of calling to the last successful is intolerably long due to engaged channels on the route to Station ...</td>
<td></td>
<td></td>
<td>*</td>
</tr>
<tr>
<td>Disconnection happens often before the end of the conversation with users from Station ...</td>
<td></td>
<td></td>
<td>*</td>
</tr>
</tbody>
</table>

The problem in this case (the general problem in factor analysis) is how to interpret revealed factors. Comparing the statements linked to the factors, it was decided to define revealed factors as follows: Factor 1 - type of user; Factor 2 - traffic on the route; Factor 3 - quality of telecommunication equipment maintenance. Then, taking into account correlations between the statesments and the factors it was infered that the main reason of the situation is the lack of telephone channels on the route (the route is overloaded) and traffic measurement on the route confirmed this inference.

5 Conclusion

In this paper the concept the evaluation of current situation on railway telecommunication network from the users point of view has been described. The main idea of the concept is as follows.

There are thousands of telecommunication services users on railways. Having elicited information from as many such users as possible and processed
the data by special procedures, telecommunication managers are able to evaluate
the current situation on the network from the users point of view.

It is possible to design research methods for identifying the "weak" parts of
telecommunication networks and then to investigate the situation in more detail
by applying traditional methods for the analysis of networks.

These research methods are not exact in the sense of the measurement of
numerical parameters of the quality of services and should be used during the
initial phases of decision-making processes for gathering information about the
telecommunication network.

Therefore, it is recommended to use these methods in addition to the well-
known ones such as measurement of traffic on the routes, percentage of
unsuccessful calls, etc.

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References

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