RAIL OPERATIONS CONTROL CENTRES

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Contribution on the State of the Art

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Abstract: The article presents an overview of common trends in the evolution of rail operations control as well as the factors stipulating the existing approaches to the design of Rail Operations Control Centres (ROCCs) around the world. Based on the comparative analysis of various ROCCs and traffic parameters, the authors propose some classification of global traffic control models. The article outlines further steps towards a more detailed analysis of ROCCs in terms of their effectiveness by introducing a number of additional criteria and performance indicators to be taken into account.

Keywords: Railway transport, Rail Operations Control Centres (ROCC), rail traffic control models, effectiveness, UIC.

INTRODUCTION

In 2021, NIIAS completed a research "Role, Design Methods and the Future of Rail Operations Control Centres in Asia" commissioned by the International Union of Railways (UIC) [1]. Presumably, this was the first global international research that covers a variety of aspects related to the design, construction and operation of Rail Operations Control Centres (ROCCs). The research presents the evolution of Rail Operations Control Centres in terms of traffic control and dispatching functionality, while taking into account such factors as the role of ROCC in traffic control, key life cycle stages, ergonomic design principles and technical requirements for ROCC hardware and software.

The research gives an overview of general principles pertaining to the design and construction of ROCCs in different countries (ROCC models), approaches to comparative analysis of ROCCs and postulates mid-term and long-term trends as regards the further evolution of ROCCs. This article presents some results of the research primarily related to the analysis of traffic control models in different countries as well as the approaches to ROCC performance evaluation.

RAIL TRAFFIC CONTROL MODELS

There are different traffic control models, and they are defined by the specifics of a particular railway network and may depend on a wide range of variables, including the geographical location, the railway network size, the railway infrastructure manager status (public, private or both), the prevailing type of traffic (freight, passenger or mixed), the transportation management process structure (centralized, decentralized), the controlled facilities, the level of the network's technical capabilities, etc.

For example, in the United States, a significant part of the railway network is owned by large private freight companies, within whose boundaries the main control centres operate. The tasks of the BNSF ROCC are determined by freight traffic in the first place, and by the operation of Amtrak passenger trains on the BNSF network in the second place.

Unlike the USA, in Europe the railways are owned by the state. In Europe, the tasks of ROCCs are determined primarily by passenger traffic, and as regards freight traffic, they can be limited by train graph issues.

In a number of countries, including such the Asia-Pacific states as China, Russia, South Korea, the network operator and traffic controller are the same company, while in other countries the railway market is in part or completely regulated by individual agencies responsible for the infrastructure and traffic management, while privatized or competing operators (primarily those of freight rolling stock) use the railway network competing for train paths. The three-tiered centralized traffic control structure appears to be the most conventional, and includes the network, regional and local levels that are typical for many countries. The traffic management system of JSC RZD is usually divided into four levels: network, regional, local levels and areas combining several railways. At each level, traffic control has its own features, which are taken into account when creating management information systems for ROCC at different levels [2].

As a result of the comparative analysis, the following traffic control models were identified:

- “American model”: ROCCs belong to big private rail freight companies; operating staff is situated in a large operations control centre, which is supported by auxiliary centres; typically, the “American model” ROCC controls bigger areas comparing to the other models;
- “European model”: the traffic control is centralized within the entire railway network and has two levels (network and regional OCCs); the regional OCCs are characterized by relatively small control areas and volumes of traffic comparing to the other models;
- “Chinese model”: the traffic control is centralized within the entire railway network and has two levels (network and regional OCCs); the regional OCCs are characterized by increased volumes of traffic comparing to the other models;
- “Russian model”: can be characterized as a hybrid model combining the features of the “American and Chinese models” and currently tending towards the “Chinese model”.

Today’s ROCC is typically a spacious and well-lit master control room with rows of automated workstations of operating personnel arranged in an amphitheater or horizontally and oriented towards the “videowall”, an Operational Visual Display System (OVDS), that visualizes a large amount of operational and analytical information on the transportation process overlaid on the layout of a railway or network. Each workstation is ergonomically designed and equipped with a modern personal computer with a number of monitors, telephones or a multipurpose touch-screen control panel. Normally, a ROCC is situated in a building of its own, and its master control room hosts a single dispatching shift that manages train traffic 24 hours a day, 7 days a week, and 365 days a year.

For the purpose of the illustration, below are given photographs of the ROCC master control rooms from around the world: the ROCC of BNSF, the largest US railway company, in Fort Worth, Texas (in terms of its size, the Centre is comparable to a football field), the Sydney Trains ROCC in the southern Sydney (Australia), the RZD ROCC (South Ural Railway) in Chelyabinsk [3].

***Photo 1:** ROCC of BNSF (USA)*

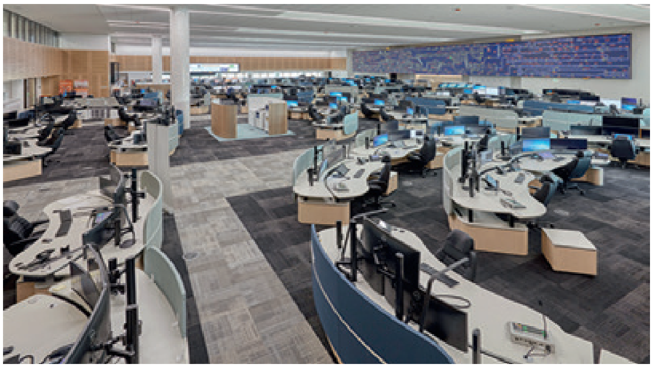

***Photo 2:** ROCC of Sydney Trains (Australia)*

***Photo 3:** ROCC of Russian Railways in Chelyabinsk*

COMPARATIVE ANALYSIS OF ROCCS IN THE WORLD

In the research, a comparative analysis of public railways was made in terms of ROCC efficiency evaluated on the basis of key performance indicators of the railway complex.

For the analysis we selected the countries with the most developed railway network: USA (BNSF, Union Pacific), Germany (DB), Austria (ÖBB), Switzerland (SBB), France (SNCF), Spain (ADIF), South Africa (Transnet Freight Rail, PRASA), South Korea (KORAIL), Russia (Russian Railways), China (CR).

It should be noted that in the examined countries not the entire railway network is “covered” by ROCCs. For example, in France, 1500 signal boxes combined into 16 ROCCs that control traffic over 14 ths km (out of 30 ths km) of the national railway network, which accounts for 90% of all railway traffic in the country. However, this factor was not taken into account in the analysis.

Network-level ROCCs were not taken into account as they generally perform coordination and monitoring functions. In cases there are no regional ROCCs, the only network-level ROCC that controls traffic is considered as a regional ROCC. At the first stage, the correlation between such parameters as the network traffic density and the number of ROCCs was analyzed.

The network performance (or network traffic density) in terms of transported freight-passengers per 1 km of track per year was calculated using formula:

$$D_n = (T_{n1}+C\cdot T_{n2})/L_n,$$

where D_n is the network traffic density, t per km of track;
T_{n1} is the annual freight turnover of the railway network, t-km;
T_{n2} is the annual passenger turnover of the railway network, pass-km;
L_n is the length of the railway network, km;
C is the passenger to freight turnover equivalence factor, C=2.

For the assessment, the initial data for 2019 were taken (as the most complete), which are given in Table 1, where *N* is the number of ROCCs.

***Table 1.** Initial data for assessing the correlation between the average network density and the number of ROCCs*

Country	Company	T_{n1}, ton-km, mln	Tn2, passenger-km, mln	L_n, ths km	N
USA	BNSF	970 882	-	52,30	5
	Union Pacific	618 170	-	57,94	4
Germany	DB	85 005	85 785	33,40	7
France	SNCF	32 039	107 920	28,00	16
Spain	ADIF (RENFE)	6 201	27 263	15,39	22
Austria	ÖBB	24 286	11 607	4,88	5
Switzerland	SBB	16 377	19 607	3,26	4
South Africa	Transnet	140 000	-	20,95	4
	PRASA	-	14 269	2,23	1
South Korea	Korail	7 878	23 002	4,08	5
China	CR	2 294 814	1 438 606	146,00	19
Russia	RZD	2 601 900	133 400	85,60	16

Table 2. *Results of the calculation of average network density*

Company	Company	Average network density (Dn), mln tons per km per year
USA	BNSF	18,6
	Union Pacific	10,7
Germany	DB	7,70
France	SNCF	8,90
Spain	ADIF (RENFE)	3,90
Austria	ÖBB	9,70
Switzerland	SBB	17,10
South Africa	Transnet	6,70
	PRASA	12,80
South Korea	Korail	13,20
China	CR	35,40
Russia	RZD	33,50

Table 2 shows the results of the calculation in terms of transported cargo passengers per 1 km of the network.

The diagram (Fig. 1) shows railway networks according to the average traffic density and the number of ROCCs. In order to see whether there is a possible correlation between these parameters, a correlation analysis was made. The resulting correlation coefficient (r = 0.3) indicates the absence of any noticeable relationship between the average traffic density and the number of ROCCs. However, it can be seen that the railway networks are arranged in several groups located in different corners of the diagram.

The first group (marked in blue) includes low-density networks with a large number of ROCCs.

The second group (marked in green) includes high-density networks with a large number of ROCCs. The third group (marked in grey) includes low-density networks with a small number of ROCCs. Further research might focus on identifying the characteristics pertaining to each group of railway networks with the additional parameters of transportation management models involving ROCCs taken into account.

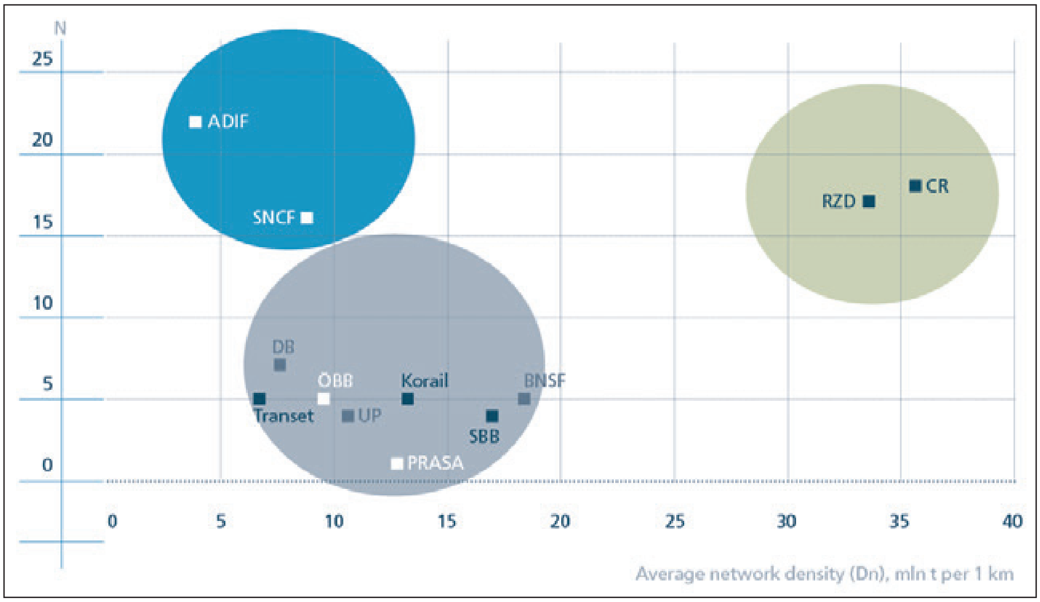

Fig. 1. *Relations between ROCCs numbers (N) and average network density*

Table 3. *Initial data for assessing the relationship between the length of ROCC controlled area and its passenger-freight turnover*

Country	Company	Average freight and passenger turnover (per OCC) mln ton-km	Average length of OCC control area, ths km
USA	BNSF	194,2	10,46
	Union Pacific	154,5	14,49
Germany	DB	36,7	4,77
France	SNCF	15,5	1,75
Spain	ADIF (RENFE)	2,8	0,70
Austria	ÖBB	9,5	0,98
Switzerland	SBB	13,9	0,82
South Africa	Transnet	28,0	4,19
	PRASA	28,5	2,23
South Korea	Korail	10,8	0,82
China	CR	287,3	7,86
Russia	RZD	179,3	5,34

The initial data for the analysis is given in Table 3.

The resulting diagram (Fig. 2) presents the railway networks according to the average length of a single ROCC's control area and the average freight-passenger turnover per ROCC. In order to see whether there is a possible correlation between these parameters, a correlation analysis was made. The resulting correlation coefficient (r = 0.75) might potentially suggest a relationship between the average length of a ROCC's control area and the average freight-passenger turnover per a ROCC.

The graph allows us to assume that BNSF, Union Pacific, CR and RZD have achieved a higher level of traffic control centralization, as one regional ROCC supervises a longer railway network with a higher freight-passenger turnover. The American model

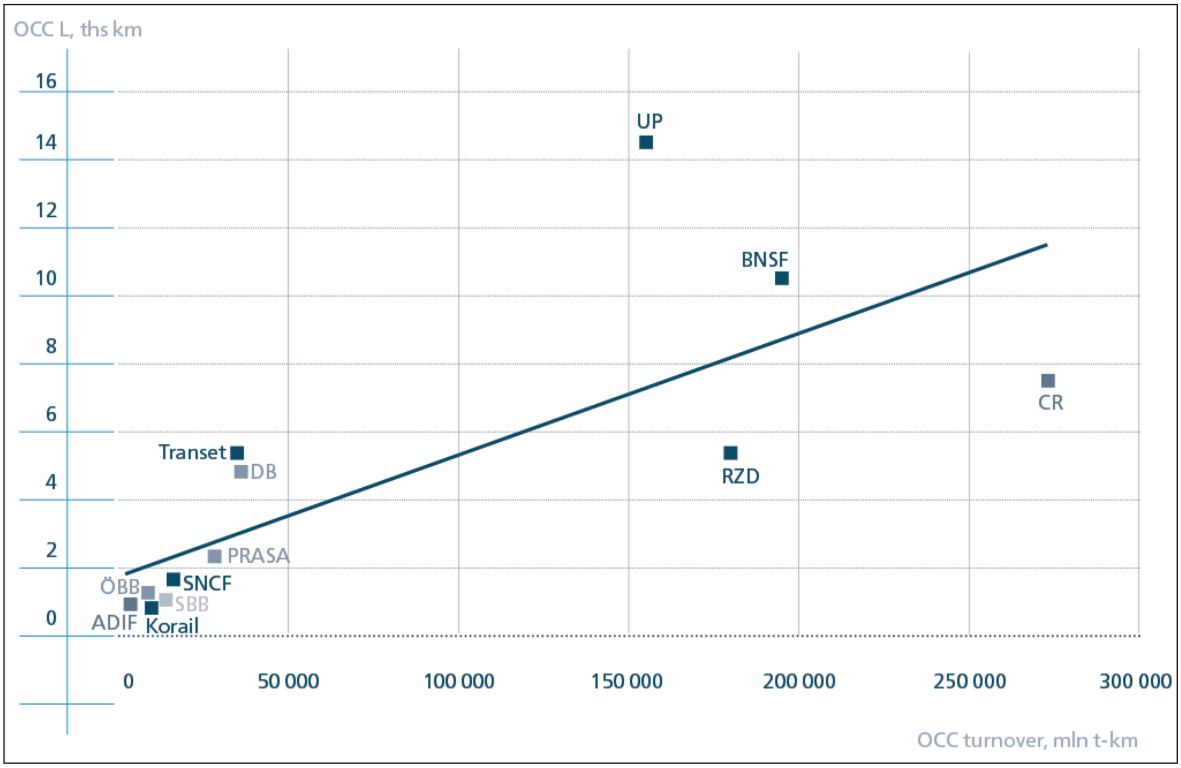

Fig. 2. *Relations between the length of a ROCC controlled area and the average passenger-freight turnover per one ROCC*

of centralized traffic control is characterized by an increased ROCC controlled area as compared to the other models, while the Chinese model involves a higher traffic managed by a single ROCC. The Russian traffic control model may probably be characterized as hybrid as it combines the features and trends of both models, yet currently tends towards the Chinese model.

The European railways as well as the railways of South Korea and South Africa can be characterized as less centralized, as one regional ROCC operates a smaller network with a lower freight-passenger turnover (Germany being evidently an exception).

This classification is rather indicative and certainly requires the consideration of additional factors affecting the transportation process management. For instance, the following factors should probably be taken into consideration: the ROCC's geographical coverage, the length of controlled areas, the number and roles of the ROCC's personnel, the number of controlled facilities, the functionality of track-side assets and the HW/SW system deployed in the ROCC, additional (besides traffic control) functions performed by the ROCC, etc.

EVALUATION OF ROCC EFFICIENCY

If one looks at a ROCC from the point of view of its performance indicators, one might probably compare the ROCCs currently existing around the world by evaluating their effect on the transportation process in terms of Key Performance Indicators (KPI). In the conventional sense, KPIs are a metric system for measuring a company's performance that takes into account the overall performance according to a certain scale. In this case, the KPI is calculated using the formula, in which all the indicators are averaged, while the passenger turnover is reduced to freight turnover:

$$I_o = \frac{L_1}{L_2} + \frac{D_1}{D_2} + \frac{T_1}{T_2},$$

Where I_o is a ROCC's operations key performance indicator (KPI);
L_1 is the length of a ROCC's controlled area (ths. km);
L_2 is the length of a ROCC's controlled area in the sample (ths. km);
D_1 is the traffic density of the infrastructure controlled by a ROCC (t per 1 km);
D_2 is the traffic density of the infrastructure controlled by a ROCC in the sample (t per 1 km);
T_1 is the freight turnover attributed to a ROCC (mln t-km);
T_2 is the freight turnover attributed to a ROCC in the sample (mln t-km).

It should be noted that L_1, D_1 and T_1 indicators are calculated using the following formulas: $L_1 = \frac{L_n}{N}$, $D_1 = \frac{T_n}{L}$, $T_1 = \frac{T_n}{N}$, while L_2, D_2, T_2 indicators are calculated as arithmetic mean primes.

Table 4. *Summarized data on ROCC KPI calculation*

Country	Company	N	Average length of OCC control area, ths km	L_1	Average annual network density, mln tons per 1 km	D_1	Freight turnover per OCC, tons-km	T_1	OCC KPI
USA	BNSF	5	10,46	2,31	18,6	1,25	194 176,40	2,45	6,01
	Union Pacific	4	14,49	3,20	10,7	0,72	154 542,50	1,95	5,87
Germany	DB	7	4,77	1,05	7,7	0,52	36 653,57	0,46	2,03
France	SNCF	16	1,75	0,39	8,9	0,60	15 492,44	0,20	1,18
Spain	ADIF (RENFE)	22	0,70	0,15	3,9	0,26	2 760,32	0,03	0,45
Austria	ÖBB	5	0,98	0,22	9,7	0,65	9 500,00	0,12	0,99
Switzerland	SBB	4	0,82	0,18	17,1	1,15	13 897,75	0,18	1,51
South Africa	Transnet	4	4,19	0,92	6,7	0,45	35 000,00	0,44	1,82
	PRASA	1	2,23	0,49	12,8	0,86	28 538,00	0,36	1,71
South Korea	Korail	5	0,82	0,18	13,2	0,89	10 776,40	0,14	1,21
China	CR	19	7,86	1,74	35,4	2,38	272 211,89	3,43	7,55
Russia	RZD	16	5,34	1,18	33,5	2,26	179 293,75	2,26	5,69

Table 5. *Ranking KPIs*

Harrington values	Modified scale values	Evaluation of KPIs
1,00 – 0,80	More than 6.04	Very high
0,80 – 0,64	6,04-4,83	High
0,64 – 0,37	4,82-2,79	Medium
0,37 – 0,20	2,78-1,51	Low
0.20 and less	Less than 1.51	Very low

A summarized data on ROCC KPI calculation in different countries is given in Table 4.

The calculation shows that the maximum KPI is 7.55. Harrington's scale can be used for constructing a metric system for estimating (ranking) KPIs taking into account the obtained maximum KPI value.

The final modified scale with estimated indicators is shown in Table 5.

As it can be seen from the Table 4, four railway networks significantly differ from the rest of the sample. Given the obtained maximum KPI and the proposed ranking system, the obtained results of a ROCC's "performance ranking" for the selected countries are shown in Table 6.

Table 6. *Assessment of ROCC efficiency level*

Country	Company	Number of ROCCs	L_1	D_1	T_1	ROCC KPI	Ranking
USA	BNSF	5	2,31	1,25	2,45	6,01	2
	Union Pacific	4	3,20	0,72	1,95	5,87	3
Germany	DB	7	1,05	0,52	0,46	2,03	5
France	SNCF	16	0,39	0,60	0,20	1,18	10
Spain	ADIF (RENFE)	22	0,15	0,26	0,03	0,45	12
Austria	ÖBB	5	0,22	0,65	0,12	0,99	11
Switzerland	SBB	4	0,18	1,15	0,18	1,51	8
South Africa	Transnet	4	0,92	0,45	0,44	1,82	6
	PRASA	1	0,49	0,86	0,36	1,71	7
South Korea	Korail	5	0,18	0,89	0,14	1,21	9
China	CR	19	1,74	2,38	3,43	7,55	1
Russia	RZD	16,00	1,18	2,26	2,26	5,69	4

The above data do not enable a rigorous mathematical analysis due to the insufficiency of open-source information, yet they might indicate the avenues of future research. In fact, the comparative analysis of ROCCs of various countries is a multi-criteria task that requires not only a more complete set of reliable data, but the use of factor analysis as well.

CONCLUSION

As part of possible further research of the role and efficiency of ROCCs in different traffic control models, it might be suggested that one should extend the ROCC evaluation criteria. It is also obvious that further research should take into account at least the following aspects:

- number and length of dispatcher-controlled areas as well as their density;
- minimum and maximum traffic management-related workload of a traffic controller;
- spatial allocation of Operations Control Centres;
- structure of the short-term transportation planning and assignment of adequate numbers of traffic control personnel;
- systems for automation traffic control and supervision, including automatic train supervision.

Despite the differences in traffic control models, it should be noted that there is a general trend in all developed countries towards a greater centralization of operational management in control centres and the strengthening of the role of ROCCs in ensuring the sustainability of the transportation process. In this sense, such ROCCs' functions as situational awareness and forecasting implemented on the basis of predictive analytics methods are becoming increasingly important. In addition, the development of ROCC is linked with improving workforce productivity in railways and optimizing CAPEX and OPEX associated with the transportation process [4].

In general, it can be said that modern ROCCs are developing in the direction of the target state of ROCC 4.0. This trend should also be taken into account when assessing the efficiency of ROCCs and updating the requirements for ROCCs as part of the development and improvement of the existing traffic control system.

REFERENCES

[1] Research Project "Role, Design Methods and Future of Rail Operations Control Centres (Ctrl4Rail)". UIC, 2021. Preprint.

[2] Ozerov A.V. Information Technologies for Traffic Management / Ozerov A.V., Drozdov A.V., Fomenkov D. Yu., Berestok N.O. // Railway Transport. – 2021. No. 12. – pp. 32-34.

[3] Rozenberg E.N. Operations Control Centres: Evolution and Expectations / Rozenberg E.N., Ozerov A.V., Berestok N.O. // Science and Technologies for Railways. – 2021. No. 3 (19). – pp. 9-14.

[4] Rozenberg E.N. The world's rail operations control models / Rozenberg E.N., Ozerov A.V., Denchik E.V. // Science and Technologies for Railways. – 2022. No. 2 (22). – pp. 3-9.

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