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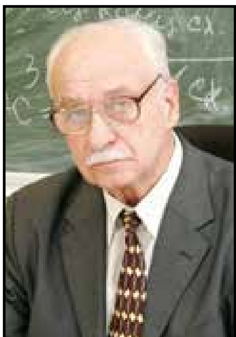
Increasing the Capacity of a Locomotive Depot by Prioritising Organisational and Technical Measures



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ABSTRACT

One of the key elements affecting the capacity of the technical station with locomotive turnover points and the entire segment of railway network is an insufficient technical equipment of locomotive maintenance points (LMP), which is a «threshold» that prevents the stability of loaded trains' traffic.

To eliminate such threshold in a particular depot and the losses associated with unproductive downtime of transiting trains, as well as to increase the efficiency of LMP operation, it is necessary to provide for a series of organisational and technical measures. Such measures may be numerous and the task to determine their priority becomes rather difficult. This complexity is explained through different significance (impact on the process) and differentiated dimensions of the criteria necessary to make decision on correct prioritisation once those criteria are compared.

The article proposes to use a special method, tested on a wide variety of practical problems, which allows selecting the best solution from the options under consideration or determining their priority (usefulness) to increase the capacity of a locomotive depot without limiting the number of decision-making criteria when considering possible organisational and technical measures.

The work proposes most promising sequence of the organisational and technical measures to be considered to improve the efficiency of LMP using the method of expert assessments based on multi-criteria assessment, which involves the information necessary to solve the problem, converting it into a dimensionless form, which allows operating the corresponding initial data regardless of their size. The transformation of information is carried out according to a deterministic algorithm and does not depend on the person that makes computations, which indicates the objectivity of the obtained result of solving the problem.

The proposed method for selecting the best option from those considered, as well as for choosing the sequence of their implementation, can also be used to solve similar problems in the absence or insufficiency of statistical data without carrying out complex economic calculations.

Keywords: *railways, freight train traffic, segment of railway network, significance factor, method of expert assessments, locomotive depot's capacity, locomotive maintenance point, LMP performance.*

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INTRODUCTION

In modern conditions, traffic control on Russian railways is characterised by a transition from regional principles of organising operational work to technology based on the traffic control over dedicated segments of railway network [«polygon technology»]. However, in practice, it is not always possible to fully implement the principle of end-to-end control because of constraints on capacity of railway lines due to the presence of bottlenecks, which, among other things, are the stations where electrical systems change. From the point of view of traction services, the Russian railway network is a sort of «patchwork quilt», at the junctions of which there are currently 25 technical stations where types of electric current change, or thresholds that limit movement of loaded trains' traffic.

Stations where types of electric current change are also stations where locomotives intended for circulation at certain sections also change. One of the so called «indicators» that determine the insufficient capacity of the station and of the entire segment of railway network, is the insufficient technical equipment of the locomotive maintenance point (LMP).

A LMP at technical stations is a system of mass maintenance of locomotives. The available capacity of the locomotive circulation area is determined among other kinds of equipment by availability of spots for performing technical maintenance of TO-2 type [further referred to as TM-2]. The size of the locomotive fleet is inextricably linked with the capacity of devices available in the depot.

The *objective* of the work is to develop solutions to increase the capacity of the locomotive depot, which, as is well known in railway transport, is one of the main possible conditions of increase in transportation productivity. The theory on which the solution to the problem is based refers to the theory of decision making that is widely used in world practice. At JSC «VNIIZhT» this theory is successfully used to solve practical problems in many areas [1–4].

MATERIALS AND METHODS

The authors use the method of expert assessments based on multi-criteria assessment and involvement of experts. The method is based on their opinion regarding the task at hand and the use of decision-making criteria. The essence of the problem is based on mathematical processing of the values of decision criteria.

RESULTS

Identification of the Limiting Element

The circulation of locomotives at a technical station «includes such elements as «from arrival to control post (CP)», «from CP to TM-2», «carrying out TM-2», «from TM-2 to CP» and «from CP to departure»» [5]. As a rule, according to statistical data, the circulation of a locomotive at a station is limited by such an element as «from CP to TM-2», where the average statistical value of waiting for the locomotive to be moved to the inspection pit is more than one hour. This is mainly due to the insufficient track development of LMP (insufficient number of tracks for carrying out TM-2 of locomotives and their low capacity) and insufficient number of spots for carrying out TM-2.

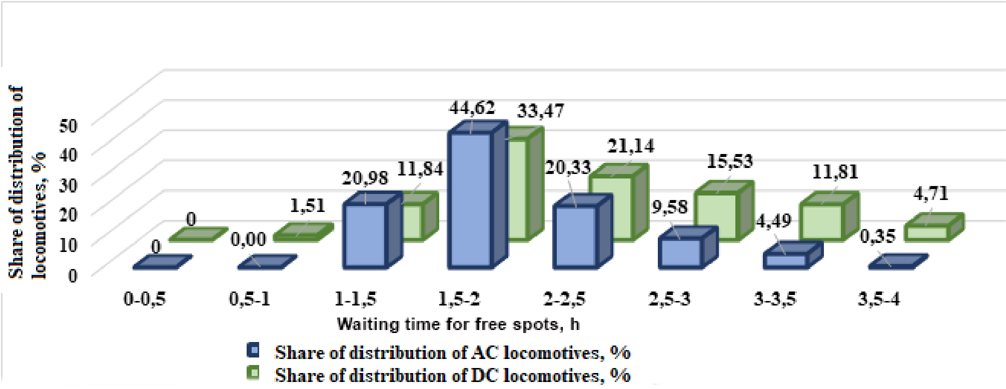
The research conducted by the authors allows us to assert (Karymskaya station of Trans-Baikal Railway, Babaevo station of Oktyabrskaya Railway) that at technical stations one of the «indicators» that determine the insufficient capacity of a station or a segment of railway network is the insufficient technical equipment of LMP.

According to statistics [5], in 2017 at Karymskaya station, 73,53 % of electric locomotives waited more than 0,5 hours for free maintenance spots, and 45,2 % of locomotives waited more than one hour. The average downtime of electric locomotives during the period under review was one hour. At Babaevo station, at the end of 2020, the share of electric locomotives arriving with trains and subject to TM-2 is 30 %, while the share of such an element as the passage by a locomotive of the control point before moving to inspection pit for TM-2 in the overall circulation of a locomotive at the station is 40 % (Pic. 1).

According to the analysis, for most of both electric AC and DC locomotives waiting time for free spots for TM-2 starts from one hour or more, while the waiting time for DC locomotives is longer and is from two to four hours.

Selection of Organisational and Technical Measures

To eliminate losses associated with unproductive downtime of transiting trains without processing while waiting for the train



Pic. 1. Analysis of downtime of DC and AC locomotives on the stage from CP to TM-2 at Babaevo station, 2020 [performed by the authors].

locomotive and delays of trains at the approaches to the station due to locomotives waiting for free TM-2 spots, as well as to increase the efficiency of LMP operation, it is advisable to provide for the following organisational and technical measures R:

1. To increase the number of inspection pits R_1 on existing LMP tracks.

2. To increase the number of tracks and inspection pits R_2 on the territory of LMP.

3. If it is impossible to develop the existing LMP territory, to consider options to place LMP with a more technically developed track system directly at the train arrival/departure yards to reduce the loss of time associated with movement of locomotives to the depot territory – R_3.

4. To switch from rigid specialisation of inspection pits to «floating, flexible» specialisation and technology (any AC or DC locomotive of any series can use any of the pits) – R_4.

5. To switch from rigid specialisation of inspection pits to «floating, flexible» specialisation due to the transition to dual-system electric locomotives – R_5.

6. To stipulate a minimum fixed time for occupation of maintenance and repair spots (revision of existing time standards) – R_6.

7. Reduction of standard time for maintenance of locomotives by increasing the number of employees (staff) of LMP – R_7.

The proposed measures will increase the capacity of locomotive depots located at technical stations of cargo-intensive sections of the Russian Railways network, which, in turn, will lead to an increase in the capacity of the stations themselves and the adjacent railway sections by reducing the time spent by loaded trains ready for departure (transit without processing) while waiting for the train locomotive, as well as to an increase in speed on the sections at the approaches to technical stations.

To solve the problem and to determine the best organisational and technical measures, decision-making criteria *K* were adopted [6; 8]:

1. Percentage of increase in the capacity of technical station, K_1 – the higher is the percentage, the better.

2. Percentage of increase in the capacity of railway sections adjacent to the technical stations, K_2– the higher is the percentage, the better.

3. Percentage of reduction in idle time of trains ready to depart while waiting for train locomotive, K_3 – the higher is the percentage, the better.

4. Percentage of reduction in the required working fleet of locomotives, K_4 – the higher is the percentage, the better.

5. Percentage of reduction in the number of locomotives reserved for technological reasons, K_5 – the higher is the percentage, the better.

6. Percentage of reduction in duration of works, K_6 – the higher is the percentage, the better.

7. Economic effect, K_7, mln rub. /year – the higher, the better.

8. Cost of work, K_{8}, mln rub. – the less, the better.

9. Costs associated with completed organisational and technical measures, K_9, mln rub. /year – the less, the better.

Decision-making criteria are proposed by qualified specialists (in this case, by experts).

An example of numerical values of criteria K_1, … K_9 for making a decision for each of the activities R_1,… R_7 is given in Table 1.

Table 1

Decision-making criteria values [performed by the authors]

Criteria	Organisational and technical measures						
	R_1	R_2	R_3	R_4	R_5	R_6	R_7
K_1, %	15	25	10	25	30	20	25
K_2, %	15	25	10	25	30	20	25
K_3, %	15	25	10	25	30	20	25
K_4, %	10	20	10	10	20	15	20
K_5, %	10	20	5	10	20	15	20
K_6, %	0	0	0	0	0	20	30
K_7, mln rub. /year	1	1,5	1,5	0,8	1	0,9	1
K_8, mln rub.	0,5	0,8	3	0,3	3	0,2	0
K_9, mln rub. /year	0,5	0,8	0	0	1	0,2	1

Prioritisation of Organisational and Technical Measures with the Method of Expert Assessments

According to the data in Table 1, it is advisable to give an assessment of the significance (importance for the process under consideration) of each K_i indicator (that is, to give a score ranking from 1 to 7 to each indicator separately for each horizontal line).

This process consists of four stages:

First stage

According to the digital values of the decision-making criteria indicated in Table 1, we determine the places of the measures under consideration from 1 to 7 (Table 2), with the best location corresponding to a larger number. The process of assigning places begins with a higher number (in our case, 7). In a particular case, within the same criterion, places for different measures may coincide.

In Table 2 places of measures R_1… R_5 according to criterion K_6 (percentage of reduction in work duration) are marked with the lowest figure due to the complete absence of this reduction.

Second stage

Let us clarify the results obtained by using linear interpolation (we will determine the refined locations of each measure according to specific criteria). «Linear interpolation is the simplest and most commonly used type of interpolation. It consists in the fact that given points with coordinates x_i, y_i for $i = 0, 1, 2, \dots n$ are connected by straight line segments, and the function $y(x)$ can be approximately represented as a broken line. The equations of each segment of the broken line are generally different. Since there are n intervals (x_{i-1}, x_i), then for each of them the equation of a straight line passing through two points is used as the equation of the interpolation polynomial: for the *i-th* interval, in general, it is possible to write the equation of a straight line passing through the points (x_{i-1}, y_{i-1}) and (x_i, y_i)» [9]:

$$\frac{y - y_{i-1}}{y_i - y_{i-1}} = \frac{x - x_{i-1}}{x_i - x_{i-1}}. \tag{1}$$

In the case under consideration, we take that $x, x_i, x_{i-1} \rightarrow \mu, \mu_i, \mu_{i-1}$, где μ, μ_i, μ_{i-1}, – places of the criterion K_i.

In this case μ – the place being specified, μ_i, μ_{i-1} – the highest and the lowest places, respectively, $y, y_i, y_{i-1} \rightarrow h$, where h, h_i, h_{i-1} – values of the criterion K_i. In this case h – value of the criterion K_i for the specified place, h_i, h_{i-1} – values of the criterion K_i for the highest and the lowest places, respectively.

Let us determine the specified places for R of each of the criteria.

For example, here we will clarify the places for criterion K_7 (economic effect) when increasing number of inspection pits on existing LMP tracks (R_1). When carrying out calculations, clarification of the lowest and highest places is not required, all other intermediate places are clarified, then formula (1) for the case under consideration takes the following form:

$$\frac{h_7^1 - h_7^4}{h_7^2 - h_7^4} = \frac{\mu_7^1 - \mu_7^4}{\mu_7^2 - \mu_7^4}. \tag{2}$$

With an increase in the number of inspection pits on existing tracks of LMP (R_1) the criterion K_7 has the value $x = \mu_7^1 = 1$ (Table 1), in terms of its significance it is in the 6th place, $y = h_7^1 = 6$ (Table 2).

Values according to Tables 1, 2 for:

• the lowest place $x_{i-1} = \mu_7^4 = 4$, $y_{i-1} = h_7^4 = 0{,}8$;

• the highest place $x_i = \mu_7^2 = 7$, $y_i = h_7^2 = 1{,}5$.

Table 2

Distribution of places assigned to measures according to the information in Table 1 [performed by the authors]

	Organisational and technical measures						
Criteria	R_1	R_2	R_3	R_4	R_5	R_6	R_7
K_1	4	6	3	6	7	5	6
K_2	4	6	3	6	7	5	6
K_3	4	6	3	6	7	5	6
K_4	5	7	5	5	7	6	7
K_5	5	7	4	5	7	6	7
K_6	0	0	0	0	0	6	7
K_7	6	7	7	4	6	5	6
K_8	4	3	2	5	2	6	7
K_9	5	4	7	7	3	6	3

Table 3

Refined distribution of the proposed criteria for selecting the most promising option of organisational and technical measures in order of significance (specified places) [performed by the authors]

	Organisational and technical measures						
Criteria	R_1	R_2	R_3	R_4	R_5	R_6	R_7
K_1	4	6	3	6	7	5	6
K_2	4	6	3	6	7	5	6
K_3	4	6	3	6	7	5	6
K_4	5	7	5	5	7	6	7
K_5	5	7	4	5	7	6	7
K_6	0	0	0	0	0	6	7
K_7	4,86	7	7	4	4,86	4,43	4,86
K_8	6,17	5,67	2	6,50	2	6,67	7
K_9	5	3,8	7	7	3	6,2	3

Then $\frac{1-0,8}{1,5-0,8}=\frac{\mu_7^1-4}{7-4}$, where $\mu_7^1=4,86$.

Thus, we find that criterion K_7 during performing the organisational and technical measure R_1 for its significance will be located not in the 6th place, but in the 4,86th place. Similarly, we clarify the places for each of the criteria under consideration and summarise the results in the Table 3. To more strictly determine the specified places, we do not round the obtained values, but leave them with the numbers after the decimal point[1].

Third stage

It is necessary to determine the significance factor for each criterion based on expert assessments. «The expert approach allows us to solve problems that cannot be solved in a conventional analytical way, including:

– choosing the best solution option among the available ones;

– searching for possible solutions to complex problems;

– receiving recommendations from specialists with knowledge and experience in a certain field» [9].

To solve the problem, independent experts in the field of the issue under study are involved (an odd number of people). «The members of the expert group are unknown to each other; interaction between group members when filling out questionnaires is completely excluded. Experts must have experience in areas relevant to the tasks being solved. When selecting experts, in general, one should consider the moment of personal interest, which can become a significant obstacle to obtaining an objective judgment» [9; 10]. This problem is not considered in this work.

Methods for obtaining individual opinions of members of an expert group are based on

[1] To more accurately distribute places of measures, it is possible to use a nonlinear approximation (Lagrange polynomial). The refinement regarding the examples given can reach 2–2,5 %.

Table 4

Criteria significance factors (0–1) [performed by the authors]

	K_1	K_2	K_3	K_4	K_5	K_6	K_7	K_8	K_9
Expert 1	1	1	0,5	0,5	0,1	0,2	0,3	0,5	0,3
Expert 2	1	0,9	0,8	0,8	0,2	0,3	0,7	0,8	0,6
Expert 3	1	1	0,6	0,6	0,2	0,2	0,7	0,6	0,4
Average value	1	0,97	0,63	0,63	0,17	0,23	0,57	0,63	0,43

obtaining information from experts interviewed independently of each other, with subsequent processing of the received data[2]. The main advantages of the individual expert assessment method are their efficiency, the ability to fully use the individual abilities of the expert, the absence of pressure from authorities and the low cost of expertise[3].

Experts are tasked with determining the significance factors of each of the considered decision-making criteria for the most promising option of organisational and technical measures from 0 to 1 (in this case, several criteria can have the same priority, the higher is the value, the better).

Based on this assessment, Table 4 is compiled and the average value of the significance factor is calculated for each of the decision-making criteria [11; 12].

Fourth stage

After obtaining the weighted average value of the significance factor, we once again clarify the distribution of the proposed decision-making criteria to determine the most promising option for organisational and technical measures according to their priority (specified places) by multiplying the corresponding place of the desired criterion (Table 3) and the resulting weighted average significance factors (Table 4). The results obtained are shown in Table 5.

According to Table 5, by adding the numbers separately for each vertical column, it is possible to obtain the recommended priority for carrying out measures R_1... R_7 according to the criteria K_1, ... K_9 when solving the problem of increasing the efficiency of LMP. A larger sum of numbers will correspond to the best organisational and technical measure according to a number of criteria under consideration [13–15].

As it can be seen, the best is measure R_7 – reducing the standard time for carrying out cyclic maintenance operations of locomotives by increasing the number of employees (staff) of LMP.

The best option for an organisational and technical measure was obtained by comparing these measures according to a set of criteria, taking into account the significance of these criteria among themselves.

CONCLUSION AND DISCUSSION

The work proposes to determine the most promising sequence of organisational and technical measures under consideration to

[2] Orlov, A. I. Expert assessments. Tutorial. Moscow, 2002, 31 p.

[3] Expert assessments. Stat Soft: SPC Consulting. [Electronic resource]: http://www.spc-consulting.ru/ app/expert.htm. Last accessed 21.03.2023.

Table 5

Refined distribution of proposed decision-making criteria when choosing the most promising option for organisational and technical measures, taking into account the significance factor of the criteria [performed by the authors]

Criteria	R_1	R_2	R_3	R_4	R_5	R_6	R_7
K_1	4,00	6,00	3,00	6,00	7,00	5,00	6,00
K_2	3,88	5,82	2,91	5,82	6,79	4,85	5,82
K_3	2,52	3,78	1,89	3,78	4,41	3,15	3,78
K_4	3,15	4,41	3,15	3,15	4,41	3,78	4,41
K_5	0,85	1,19	0,68	0,85	1,19	1,02	1,19
K_6	0	0	0	0	0	1,38	1,61
K_7	2,77	3,99	3,99	2,28	2,77	2,53	2,77
K_8	3,89	3,57	1,26	4,095	1,26	4,20	4,41
K_9	2,15	1,63	3,01	3,01	1,29	2,67	1,29
Sum of values	23,21	30,39	19,89	28,99	29,12	28,58	31,28

increase the LMP capacity using the method of expert assessments when solving a multi-criteria problem.

It should be noted that when solving the problem of increasing the capacity of the locomotive depot, the best measure turned out to be a growth of LMP staff. The obtained result can also be justified by the fact that carrying out other measures, for example, such as increasing the number of inspection pits on existing LMP tracks, increasing the number of tracks and inspection pits on the territory of LMP, etc. require significant financial and time expenditures. Such decisions in conditions of shortage of capacity, especially on cargo-intensive routes, when the issue needs to be resolved «here and now», may not always be rational, which was confirmed by the study.

The proposed method for selecting the best option from those under consideration, as well as the sequence of their rational implementation according to many criteria, based on expert assessments, can be used to solve problems similar in formulation of the question, when it is necessary to obtain an objectively best solution from those under consideration.

REFERENCES

1. Gogrichiani, G. V. Objective determination based on the results of comparisons (tests) of a promising object with an unlimited number of conflicting criteria under consideration [*Obektivnoe opredelenie po rezultatam sravnenii (ispytanii) perspektivnogo obekta pri neogranichennom mnozhestve rassmatrivaemykh protivorechivykh kriteriev*]. *Vestnik VNIIZhT*, 2006, Iss. 6, pp. 14–15. EDN: HYOKXV.

2. Gogrichiani, G. V., Lyashenko, A. N. Regular method for solving problems of finding the best option from those considered in relation to the transport complex [*Regulyarniy metod resheniya zadach po nakhozhdeniyu luchshego varianta iz rassmatrivaemykh primenitelno k transportnomu kompleksu*]. *Proceedings of I International Scientific and Practical Conference «Science 1520 VNIIZhT: Look beyond the horizon»*. Moscow, JSC VNIIZhT, 2021, pp. 83–86. EDN: YFFVLU.

3. Gogrichiani, G. V., Kazarinova, D. A. Selection of a promising anti-skid device from a considered set based on contradictory criteria [*Vybor perspektivnogo protivoyuznogo ustroistva iz rassmatrivaemykh po sovokupnosti protivorechivykh kriteriev*]. *Vestnik VNIIZhT*, 2014, Iss. 6, pp. 26–32. EDN: TOLHNF.

4. Macheret, D. A., Gogrichiani, G. V., Syrodoeva, T. I. Economic and mathematical approach to issues of movement of personnel in railway transport organisations [*Ekonomiko-matematicheskiy podkhod k voprosam kadrovykh peremeshchenii v organizatsiyakh zheleznodorozhnogo transporta*]. *Ekonomika zheleznykh dorog*, 2015, Iss.37, pp. 68–76. EDN: UAECKN.

5. Mekhedov, M. I., Kornienko, N. V. The influence of technical and technological equipment of a locomotive maintenance point on the capacity of a railway line [*Vliyanie tekhnicheskogo i tekhnologicheskogo osnashcheniya punkta tekhnicheskogo obsluzhivaniya lokomotivov na propusknuyu sposobnost zheleznodorozhnoi linii*]. *Vestnik VNIIZhT*, 2021, Vol. 80, Iss.4, pp. 225–232. EDN: DDAGDB.

6. Kini, R. L., Raifa, H. Decision-Making under Various Criteria: Preferences and Substitutions. [Russian edition] Ed. by I. F. Shakhnov; transl. from English by V. V. Podinovsky *et al*. Moscow, Radio i svyaz publ., 1981, 560 p.

7. Kotenko, A. G. Methodology for risk-based planning of quality indicators of railway operational performance. D.Sc. (Eng) thesis [*Metodologiya risk-orientirovannogo planirovaniya kachesvennykh pokazatelei ekspluatatsionnoi rabotoi zheleznykh dorog. Diss…dokt.tekh.nauk*]. St.Petersburg, PGUPS publ., 2014, 330 p. EDN: ZPKMED.

8. Kotenko, A. G. On approaches to reducing the computational complexity of logical problems of risk analysis [*O podkhodakh k snizheniyu vychislitelnoi slozhnosti logicheskikh zadach analiza riska*]. *News of St. Petersburg State Transport University*, 2011, Iss. 1 (26), pp. 180–188. EDN: NTZCGJ.

9. Danelyan, T. Ya. Formal methods of expert assessments [*Formalnie metody ekspertnykh otsenok*]. *Economics, statistics and computer science,* 2015, Iss. 1, pp. 183–187. EDN: TQJPJL.

10. Orlov, A. I. Expert assessments [*Ekspertnie otsenki*]. *Zavodskaya laboratoriya*, 1996, Vol. 62, Iss. 1, pp. 54–60. [Electronic resource]: http://orlovs.pp.ru/stat/s3p8exp.zip. Last accessed 25.04.2023.

11. Emelyanov, S. V., Larionov, O. I. Multicriteria methods of decision making [*Mnogokriterialnie metody prinyatiya reshenii*]. Moscow, Znanie publ., 1985, 32 p.

12. Larichev, O. I. Decision making as a scientific area: methodological problems. Systems research. Methodological problems. Yearbook [*Prinyatie reshenii kak nauchnoe napravlenie: metodologicheskie problemy. Sistemnie issledovaniya. Metodologicheskie problemy. Ezhegodnik*]. Ed. by D. M. Gvishiani, V. N. Sadovsky. Moscow, Nauka publ., Iss. 14, 1982, pp. 227–243. [Electronic resource]: https://raai.robofob.ru/about/persons/laritchev/papers/text/Larichev_1982.pdf. Last accessed 25.04.2023.

13. Aven, T. Misconceptions of Risk. John Wiley and sons Inc., 2010, 264 p. ISBN 978-0-470-68388-0.

14. Aven, T. Risk Analysis: Assessing Uncertainties Beyond Expected Values and Probabilities. John Wiley and Sons Inc., 2008, 208 p. ISBN 978-0-470-69443-5.

15. Aven, T., Vinnem, J. E. Risk Management: With Application from the Offshore Petroleum Industry. Springer, 2007, 211 p. ISBN 978-1-84628-652-0. ●

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