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PREDICTION of THE TRAIN TRAFFIC WHEN RANDOM FAILURES OCCUR

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INTRODUCTION

The forecast of random delays is required either when building the base schedule or during the rescheduling of disturbed trains traffic

Information on expected delays allows the dispatcher to assign adjustments that improve the process of movement

Adaptive management of freight traffic gives particularly large effect. The reason is a lot of freedom in choosing the optimal speed profiles and local routs of freight trains

We examine the process of delays' multiplication in the flow of trains.

We use the statistical model and the analytical method for computing of the probability density of train arrivals

The result of calculation is used for on-line justification of the schedule adjustments

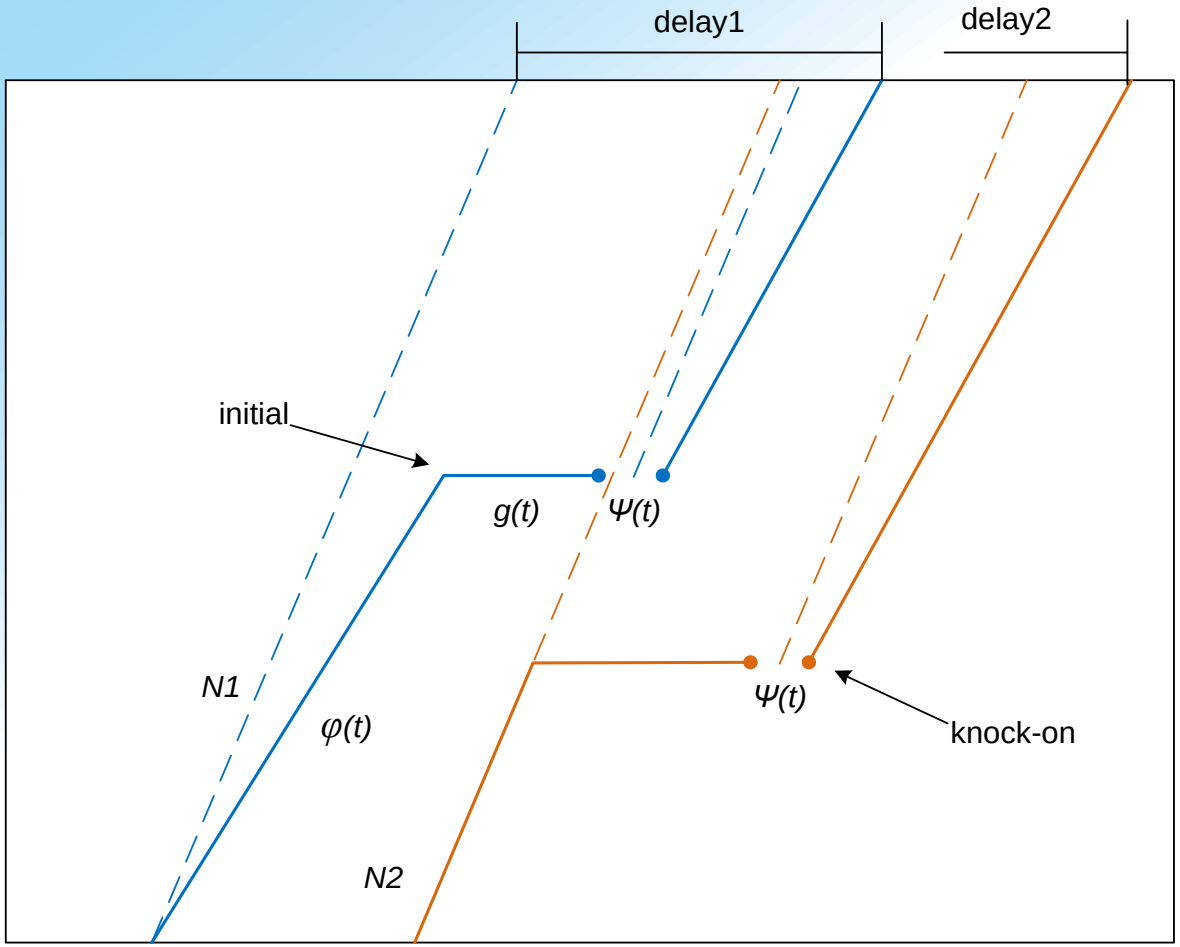
1 CRITERIA FOR THE TRAIN TRAFFIC OPTIMIZATION

- Criteria of the passenger traffic
  - ✓ punctuality:
    - smallest arrival delays
    - connections reliability
- Criteria of the freight traffic
  - ✓ effectiveness:
    - income maximum
    - costs minimum

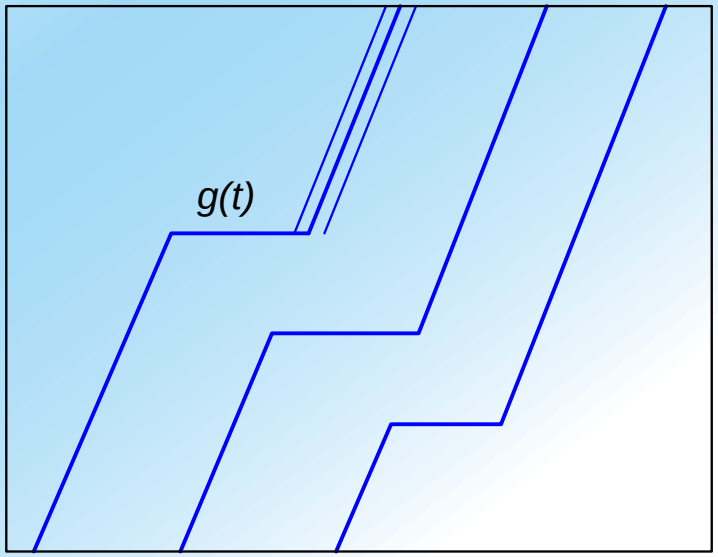
The main reason of operating economic losses are unscheduled stops

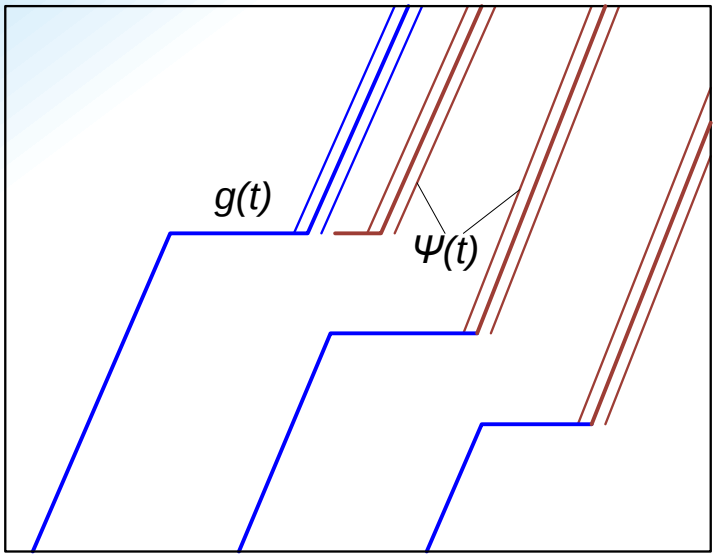
Appropriate objective function: $\sum_{i}^{N^{st}} n_i^{st} \rightarrow max$

2 GENERALIZED STATISTICAL MODEL OF FORMATION THE DELAYS



MODELS OF THE KNOCK-ON DELAYS FORMATION





statistical knock-on delays:

- ✓ due to the initial stop variation
- ✓ due to the initial stop variation and the start time scattering

3 STATISTICAL ANALYSIS: GENERAL CONSIDERATIONS

- ✓ Arrival time distribution is the composition of random deviations the operations time

- ✓ Discrete distributions are usually used for the disturb traffic modeling

  The shortage: - *computationally quite expensiveness*
  - *lack of theoretical analysis*

- ✓ Analytical approach is theoretically complicated.
  But strict solution makes it possible to study the influence of initial distributions at the arrival times in detail

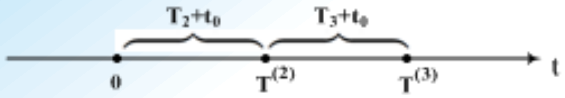
- ✓ We use theoretical results about the properties of the output (arrival) density to determine the optimal schedule

COMPUTATION OF THE ARRIVAL TIMES DISTRIBUTION

Initial probability distributions:

$g(t)$ random time of the primary stop

$\psi(t)$ distribution of the departure moments due to the random tardy driving and the facility features



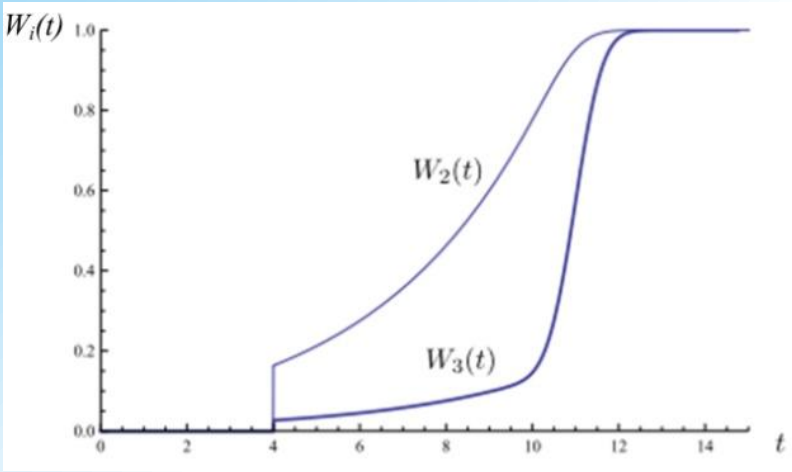
Train departure times in the case $\tau < T_2$; t_0 - safe time interval

Cumulative distribution function of the time interval between the arrivals of trains with numbers $(k-1)$ and k

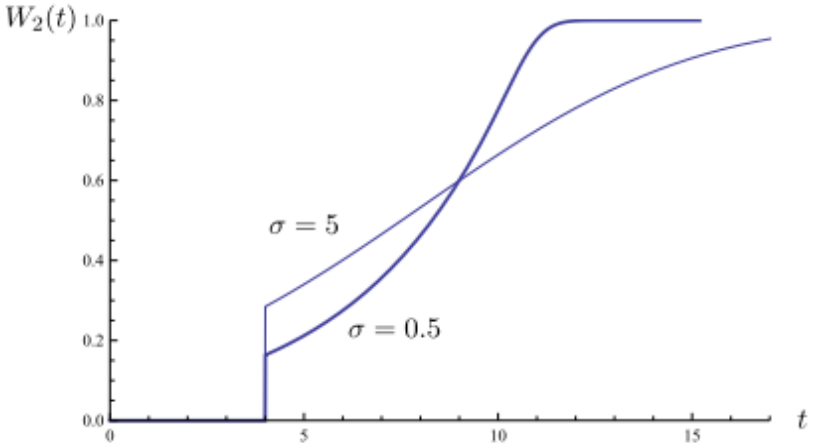
$$W_k\ t\ = I\ t > t_0 \left\{ \int_{-\infty}^{t-t_0} \psi(z)\,dz + \int_{-\infty}^{\infty} \left[\int_{t-t_0}^{\infty} \left(\int_{z+u-t+t_0}^{\infty} g(x)\,dx \right) \psi(z)\ dz \right] \psi^{*(k-2)}(u)\,du \right\}$$

ARRIVAL TIME DISTRIBUTIONS WITH THE REAL WORLD PARAMETERS

Main Russian Railways traffic parameters (average)		
	headway	$T = 7$ *min*
	safe interval	$t_0 = 4$ *min*
Real initial distributions:		
primary unscheduled stop	exponential density $g(t)$	$\lambda = 0,26 \frac{1}{\text{min}}$
random departure time	normal density $\psi(t)$	$T = 7$ *min*, $\sigma = 0.5$ *min*



a)



b)

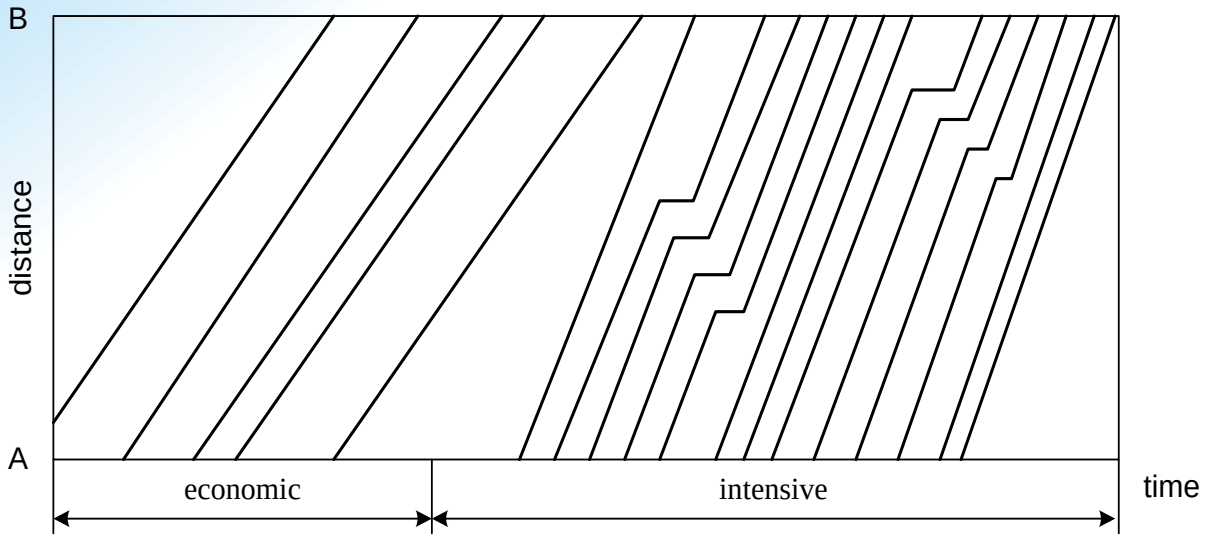
a) densities for the arrival intervals of the 2-nd and 3-rd trains;
b) densities for the 2-nd train with the different initial headway scattering

OPTIMAL FREIGDT TRAFFIC ADJUSTMENTS

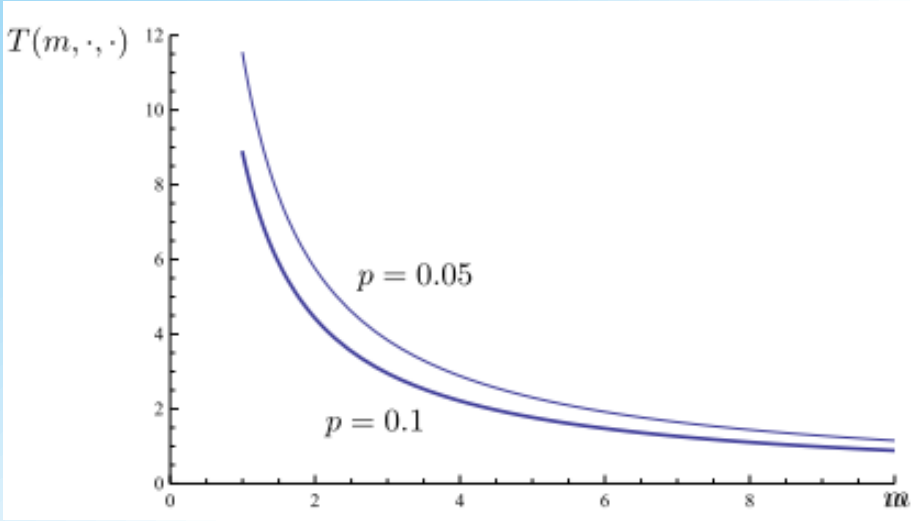
Feature of mixed traffic: different intensity of the flow of trains at various times

The certain volume of time and energy is lost at each stop
The initial headway should be increased to reduce the number of knock-on delays and the appropriate losses

Optimal dispatching assumes maximizing of the headway and increase of the time margins



OPTIMAL HEADWAY OF HEAVY FREIGHT TRAINS



Dependence of departure interval on the number of expected unscheduled delays in the presence of their various probabilities p

- ✓ The calculated interval represents 13 minutes when m_{knock} is equal to 1
- ✓ The headway of heavy freight trains at the Russian railways lies in the range from 10 to 14 minutes

CONCLUSIONS

1. Analytical stochastic approach hive new opportunity to solve the real-time rescheduling problems.

2. Dispatcher reasonably assign the periods of use the economy and the intensive mode of freight traffic.
The calculated interval is defined in this paper serves as a boundary between these modes.
Speed profiles of the trains should be adjusted so that the maximum saving energy.

We plan to develop an algorithm for computing the boundary headway, that is designed for use in the dispatching DSS. The calculation will take into account the real situation, which determines the delay statistics.

Thanks for your attention

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