Redesigning the layout of an existing railway station according to the tsi and ordinance no. 55 reqirements in the case of uninterrupted mainline operation

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Abstract: *In this paper, the problems in redesigning a new track layout of an existing railway station according to the reqirements in the TSI "Infrastructure" and Ordinance No. 55 are examined and analyzed in the case of maintaining mainline operation during construction. The paper has been compiled on the basis of experience in designing the track layout of 3 existing railway stations from the Bulgarian network, as well as experience working with the current regulations and interoperability reqirements of the railway systems in the EU. The necessities for making changes in vertical and horizontal track alignment and switch layout are considered in opposition to the technological, electrical and gauge limitations when carrying out construction works without the complete disruption of railway traffic. The conclusions of the report are formulated as guidelines for good practices when redesigning an existing layout – the practices that fully satisfy the imperative norms and balances between contradictory requirements.*

Ключови думи: interoperability, railway switches, railway stations, subsystem railway

1 Introduction

As the existing track on No IX railway mainline (fig. 1) /*categorized as part of the comprehensive railway network according to Order No 601/21.03.2018 of the NRIC*[1]/ is reaching a near-emergency condition and a relatively dense freight traffic on a national basis is observed, technical designs for the reconstruction of sections of the line were assigned. Technical design projects were prepared for the reconstruction of the Razgrad, Hitrino and Pliska railway stations. The following key factors in designing the track layouts were took into consideration:

- Preservation / Restoration of the mainline design speed in the main track through the railway station
- Design track geometry on the rest of the tracks in the station that satisfies the requirements for at least 40 km/h
- Relocating existing tracks when additional space is necessary for the construction of platforms considering the requirements of [1], [2] and [10]
- Supplying all arrival-departure tracks with stub 'safety' tracks as prescribed in art. 130 [3]
- Increase, if possible, the useful lengths of tracks for achieving the parameters prescribed in Order №601

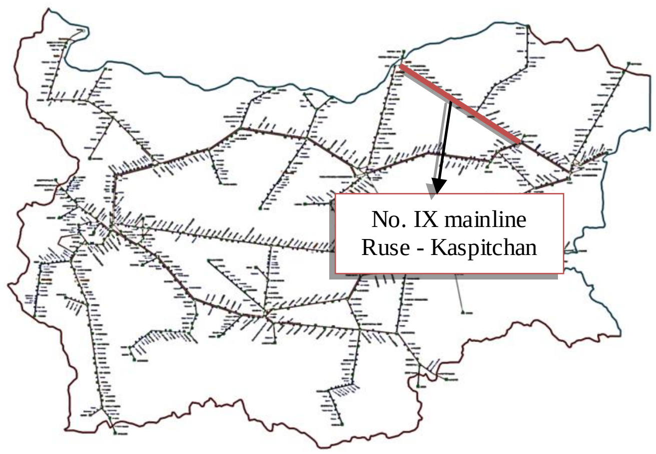

Fig. 1 *Schematic railway network map of the Republic of Bulgaria, as of 2021, No IX mainline*

This report outlines the problems in designing the track layouts of these existing stations, which were first built and then reconstructed in the late 19th and 20th centuries respectively. The three stations - Razgrad, Hitrino and Pliska, shown in fig. 2 with their existing track layouts represent a challenge from the point of view of finding and developing a design solution, which at the same time satisfies the modern requirements for an interchange railway station and optimizes to the greatest extent the financial resources invested in the reconstruction.

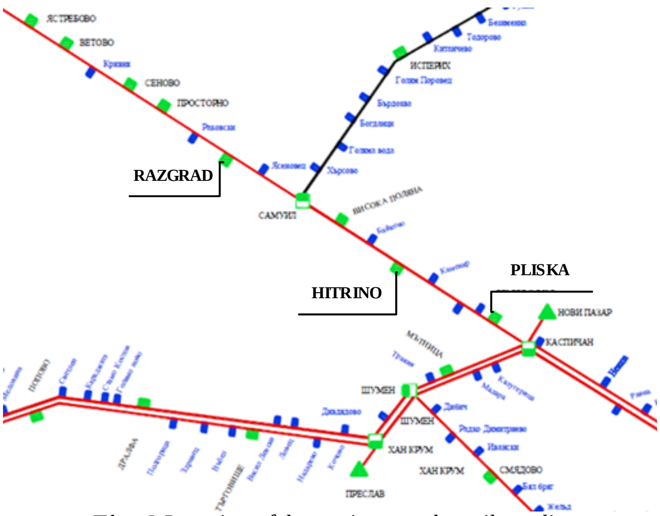

Fig. 2 *Location of the stations on the railway line*

2 Theoretical overview of the mutual arrangement of railway switches

2.1 From the aspect of railway track geometry

Switches are railway superstructure elements with pre-established and standardized geometric construction. This imposes geometric constraints on the line of the railway track in the horizontal and vertical plains. It is not possible for the two diverging tracks, which are parts of a switch, to have a different slope or a different level in the switch zone, as the two tracks lie on the same sleepers. Another limiting factor consists of the dynamic effects observed when a railway vehicle passes through the different parts of the switch. As a rule, new designs avoid dynamically dependent elements of the track geometry, which puts railway switches and their location in a key position in the plan and profile design of the railway line.

Switches include in their geometry a non-zero curvature element. I.e. this curve must be appropriately located, considering surrounding track geometry conditions.

Since the vehicles have a spring suspension, any change in the dynamic parameters of movement (speed, acceleration, first derivative of acceleration, jerk) leads to oscillations of the sprung masses. If the next element of the track changes the dynamic parameters of motion before the previous oscillations have subsided, this creates a possibility of resonance. We observe phenomenon most frequently in closely spaced horizontal curves. Such curves are dynamically dependent. As a rule, new designs avoid dynamically dependent curves, as their design is imperatively

[1] National Company for Railway Infrastructure

prohibited in [3] by instating the minimum value of the length of a straight element between two tangency points:

(1) $L_{str} \geq 0.70 * V_d \ (V_d = 160 - 200\ km/h)$

(2) $L_{str} \geq 0.50 * V_d \ (V_d < 160\ km/h)$

where L_{str} is the length of the required intermediate straight element, V_d represents design speed.

In Ordinance №55 the minimum distance between BS /*Begin Switch*/ or ES /*End of Switch*/ and the respective horizontal alignment tangency points is given as a constant of 25m (can be reduced to 6m as an exception). For track layouts in railway stations, only the minimum of 6m between two reverse curves is given. The ordinance allows for reverse curves with a common point of tangency in railway stations, but with a design speed restriction according to the selected radii without prescribing an analytical expression as a criterion.

In [4] the requirements are developed in more detail, taking into account the speed of movement. In order to validate a reverse curve without intermediate straight, both conditions must be met simultaneously:

(3) $\frac{R_1.R_2}{R_1+R_2} \geq \frac{V^2}{9}$

and

(4) $\frac{R_1.R_2}{R_1+R_2} \geq 100$

where R_1 is the first curve radius, R_2 – the reverse curve radius, V – design speed

Failing to satisfy the first condition gives:

(5) $L_{str} \geq \frac{V}{10}$

Failing to satisfy the second condition gives:

(6) $L_{str} \geq 10\ m\ (6\ m)$

Expression (3) limits the abrupt change in lateral acceleration.

2.2 From the aspect of nearby switches

The railway switch allows for the branching of one track into two - ie. three directions - one outgoing at the BS point and two incoming in the ES points. On each of the three directions can be located an adjacent switch with a variation of its three directions. An orientation with the BS point has another case – with a left and right deviation. Three possible directions with four positions for the next switch gives a total of 12 possible configurations for the placing of 2 adjacent switches (Fig. 3).

The mutual placement of railway switches is covered by the norms, providing instructions for 7 out of the aforementioned 12 cases. A rule for placement of long sleepers after the ES point is indicated. A formula for obtaining the required distance as a function of the transversal track distance is given. A table is given with pre-calculated necessary straights to ensure a minimum distance of 4750mm for two adjacent tracks. As for the other 5 special cases, the designer has to assess the required distances between adjacent switches thus ensuring their adequate mutual placement.

3 Existing and proposed track layouts

3.1 Razgrad station

The existing Razgrad station (Fig. 4) has 4 arrival-departure tracks and 3 shunting tracks. One of the arrival-departure tracks has been dismantled. Since the main track is the second one and arrival-departure tracks are located on both sides of the mainline, it was necessary to implement two safety stub tracks according to Art. 130 [3]. The placement of the stub tracks within the existing property boundary is constrained by the presence of existing office buildings, poles of the catenary and masts of the station lighting.

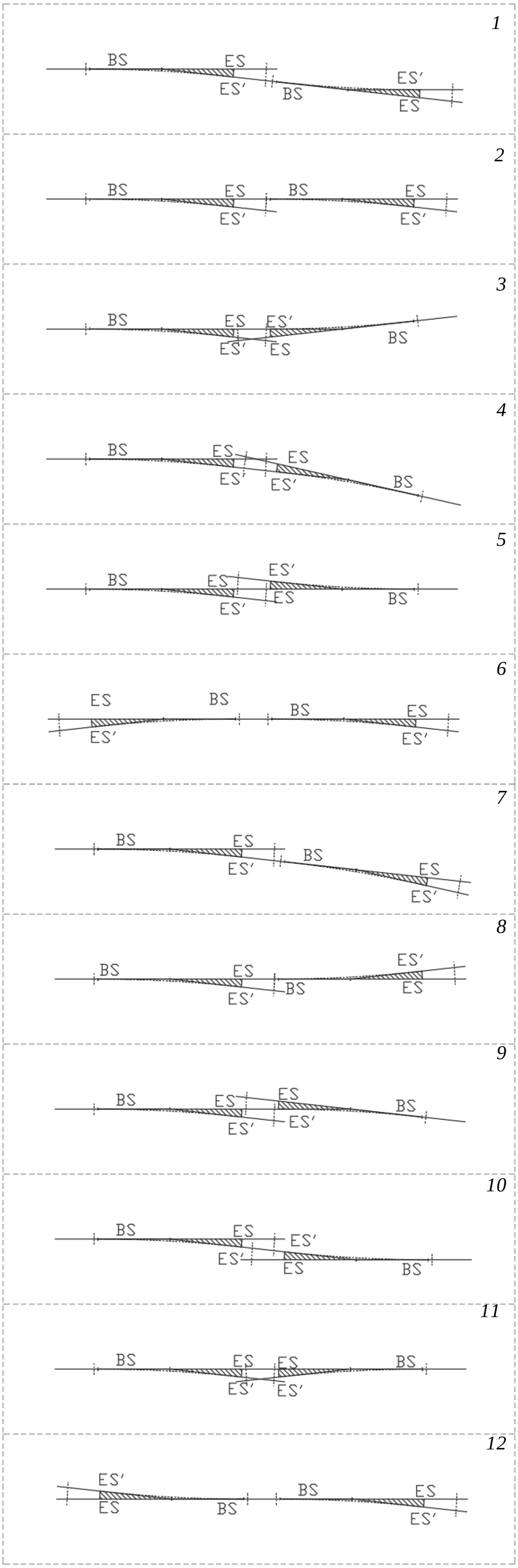

***Fig. 3** Mutual placement of two railway switches – possible cases*

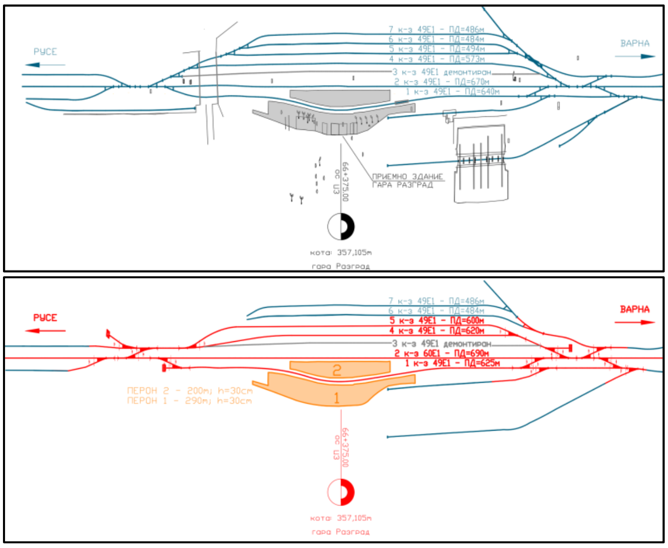

Fig. 4 Schematic view of Razgrad station – Existing and proposed layout

A serious limitation at the beginning of the station on the Ruse side was the fact that on the main track lie switches No. 2 and 4 leading to private sidings (Fig. 5), whose property limit lies on the automatic derailleurs immediately after the distance signs of the switches. Immediately after switch No. 4 follow switches No. 6 and 8, which unfold the track layout of the station. In this case, it was considered appropriate to connect the northern industrial siding (without construction activities before the derailleurs) directly with tracks 4 and 5, while providing a new rail connection to the mainline. In this way, the following improvements in the station layout are achieved:

- Fewer switches located on the mainline
- The possibility for unauthorized exit of a vehicle on the mainline from the private siding is excluded

At the end of the station (Varna) no changes are required - the arrival-departure tracks are guarded by the shunting sidings on both sides of the mainline. The position of the last switch on the mainline is limited by the subsequent horizontal curve after the station.

Fig. 5 Switches No. 2 and 4, Razgrad station

3.2 Pliska station

The existing station (Fig. 6) has 3 arrival-departure tracks, the mainline being a second track. To meet the requirements, a solution with 4 rail connections and 4 stub safety tracks is required - the solution doubles the number of switches in the station. Given that the horizontal alignment of the station is straight – a change in the layout is not appropriate – any change would impose new curves in the layout, which is not favorable from an operational point of view.

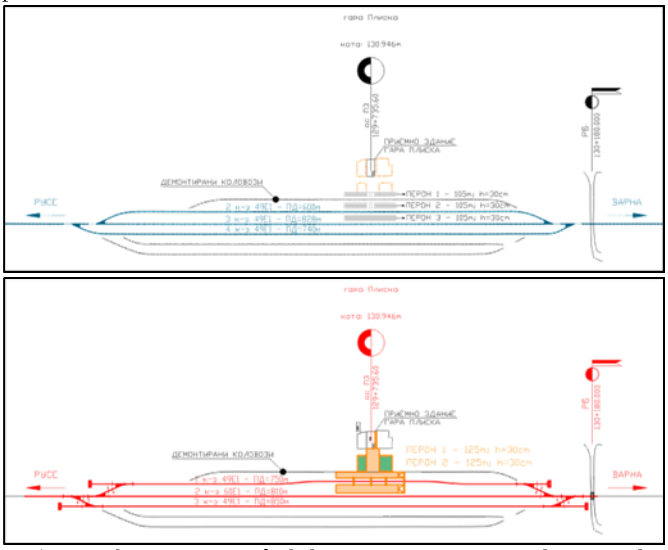

Fig. 6 Schematic view of Pliska station – Existing and proposed layout

On the other hand, as can be seen in the proposed layout, two pairs of reverse curves were implemented on the first track - a decision that was dictated by the need to construct a platform with a sufficient width to meet the requirements for unobstructed routes [2] and [10]. Although a platform height of 300mm is explicitly stated as permissible for the Bulgarian railway network in item 7.7.3.1 [1], the overall dimensions of the same were proposed so that in future reconstruction of the platform from 300mm to 550mm in height does not require a change in the geometry of the layout.

3.3 Hitrino station

The existing station (Fig. 7) has 4 arrival-departure tracks, the mainline being a second track. If the existing layout of the station is preserved, 4 stub safety tracks will be needed. However, with a change in the geometry of the mainline, it is possible to restructure the station so that the mainline passes through track 4 – thus all other tracks lie on the right side of the mainline and only one stub track is needed for each end of the station.

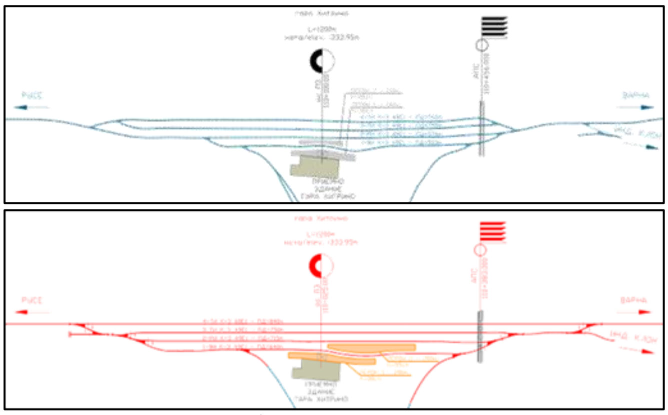

Fig. 7 Schematic view of Hitrino station – Existing and proposed layout

The proposed layout is favorable in terms of the following factors:

- Mainline design speed is restored – it rises form 60 km/h to 80 km/h
- Proposed horizontal and vertical geometry of all tracks is fully compliant with applicable norms
- Supplying all arrival-departure tracks with stub safety tracks according to the requirements of art. 130 [3] is observed with a

minimum number of additional switches and railway / *in fact - the proposed layout has 10 switches, as much as the existing one* /

- The useful lengths for achieving the parameters prescribed in Order №601 are increased – track 1 from 503m to 640m, track 2 from 576m to 715m, track 4 from 765m to 840m.
- More optimal use of the station's capacity - the heavier freight trains pass through the fewest number of switches. Upon consultation with the 2020 train schedule, it was established that there are a total of 31 scheduled trains in both directions in the Samuil-Kaspitchan section. According to the schedule of BDZ-PP, 8 passenger trains run in the same section. I.e. 26% are passenger trains. Given that freight trains have a higher axle load, it is considered rational to specialize mainline and the 3rd track as arrival-departure tracks since they are accessed through the least number of switches.

In opposition to the above - the proposed layout does not lack shortcomings:

- Each passenger train scheduled to stop at the station must pass through all switches (in case of arriving on the first track)
- Changing the mainline alignment to pass through track 4 implies replacement of the entire subballast and base structure above the existing datum surface, since the requirements regarding mainline base soil properties are the strictest. In the course of the site surveys, a vertical deformation / *indication of a weak spot in the base* / was registered, cf. Fig. 8, **exactly** on existing track 4. Therefore, the design included additional subbase layers, which increased construction costs.

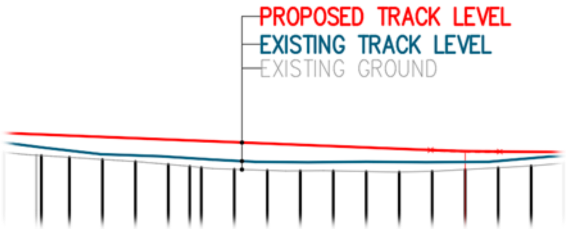

Fig. 8 *– Vertical deformation zone on existing track 4*

4 Technical limitations in changing existing railway station layouts

The most favorable method for the construction of a new railway station or the complete reconstruction of an existing railway station is the one in which all railway traffic is redirected – the catenary is switched off, no rolling stock gauge limitations are imposed. The construction time, respectively the construction costs decrease. However, this method is rarely applicable to mainlines with trains frequently passing. The additional costs of rerouting freight trains and transboarding passengers to other vehicles exceed the cost reduction achieved through continuous construction process that is unrestricted by railway traffic.

As according to current schedule more than 20 freight trains pass through the mainline in each 24 hours, and most of the trains being international, it is imperative to limit the need for traffic interruptions to a minimum by designing the proposed track layout appropriately.

Any change in the location of switches and tracks in a station intended for reconstruction is a decision that must be well justified - and above all technically feasible. This section of the report contains factors missing in current applicable norms and regulations that must be taken into account while designing a proposed layout.

4.1 Relocation of existing tracks

Preserving the possibility for a busy interchange station on a single-track mainline to continue to operate during construction is a key factor. In the general case, this presupposes the presence of at least two arrival-departure tracks at any time during construction with a working catenary network and with provided construction and rolling stock gauge.

4.2 Relocation of existing switches

Another key factor is the location of existing switches. In electrified stations (as considered in this report) above each switch there is a catenary line crossing (Fig. 9) so that both tracks have their adjacent traction power supply. Any displacement of a railway switch imposes a displacement of the catenary line crossing, which in turn imposes erection of a new pole for tensioning the adjacent catenary.

Fig. 9 *Catenary line crossing*

4.3 Proposed track layout in the zone of level crossings

According to Art. 21 [9], the level crossings are brought in line with the Ordinance when reconstructing the adjacent roads. However, the reconstruction of tracks through the level crossing often leads to a change in the level or the position of the rail head in the area of the level crossing. This means that during the construction work the level crossing will be completely closed for a certain time. It is necessary to assess the socio-economic significance of the level crossing, as well as the availability of bypass routes, which is especially important for special vehicles (ambulance, fire brigade, etc.). In the case of Hitrino station, through the tracks of which passes the main street of the settlement, the bypass route has a length of over 6 km (Fig. 10). During construction activities, the contractor will rebuild the crossing taking into account existing slopes on the adjacent street.

Fig. 10 *Bypass route around the closed level crossing, Hitrino station*

5 Conclusion

In this report, theoretical and practical formulations in the design of new track developments at existing intermediate railway stations were considered. It is obvious that not only the quality of the geometry and construction of the railway itself, but also the future functionality of the station with all its' subsystems depends on the designer of the "Permanent way" project part. Safety and sustainability of railway traffic during construction depend on the design decisions in the "Permanent way" project part.

Conflicting requirements stand out. On one hand there are the regulatory restrictions on the mutual placement of switches. On the other hand –at existing stations on the railway network adjacent switches are frequently laid without intermediate straights. Redesigning the layout to conform with requirements for placement of switches imposes a reconstruction of the catenary, which is not compatible with continuous uninterrupted railway traffic during construction.

The key parameters that the design must comply with in order to be feasible are:

- Horizontal, vertical geometry of the railway, placement of the switches, track distances, distances to existing buildings and facilities intended for preservation.
- The rigid points for the plan and profile of the railway - the end switches in the station, entrance and exit signals, level crossings, retaining walls, bridges, etc.
- The available space within the property boundaries of the railway infrastructure, as compared to the requirements of the Contracting Authority regarding the reconstruction of the station (new tracks, widening platforms, increasing the length of the station, new stub safety tracks, etc.)
- The interoperability requirements of the subsystem "Infrastructure" and "Persons with reduced mobility" – line categorization, design speed, train length, axle load, usable length of the platforms, gauge and accessible environment for passenger traffic
- The future safety of the station operation during shunting activities and train receiving and dispatching activities (avoidance of hostile routes, minimum number of switches on the mainline, limiting the access to the mainline from other sidings or tracks)
- Consideration of the possibilities for constructing the catenary according to the proposed track layout
- Considering variants for implementation of construction: possible stages of construction, temporary traffic on adjacent tracks, temporary platforms and temporary access of passengers to the station during construction activities

Taking into account the above factors, as well as the identification of other project-specific features implies improving the quality, productivity and safety of the railway infrastructure at the expense of optimal capital investments for its reconstruction.

6 Literature

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[4] Instruction for construction and maintenance of the superstructure of the railway and railway switches, Sofia, 2018.
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[5] Razgrad station instruction of operations, NRIC
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[8] Train schedules 2010 - 2020

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