MODEL SIMULATION OF THE EFFECTS OF NEWLY LAID RAILWAY LINES ON GOODS TRAFFIC

P. Kessel

Beratergruppe Verkehr + Umwelt
Schwimmbadstr. 15
7800 Freiburg
Germany

1. SURVEY

The German Federal Railway ist having two newly laid lines constructed between Hannover and Würzburg, as well as between Mannheim and Stuttgart. Additional new lines, which will make the railway network of the German Federal Railway decisively more efficient and attracting are being planned at present.

All these lines are indeed primarily conceived for passenger long-distance traffic, but also have to a large extent effects on the long-distance traffic of goods; because after the realization of the newly laid lines within the already existing network the agreement will have more capacities at its disposal. Because of this, goods traffic provides a most decisive useful contribution in the economical evaluation of newly laid lines in the network of the German Federal Railway.

In the scope of the so-called "Federal Traffic Planning" (BVWP), the Transport Minister lets all road, rail and inland navigation investment programmes be newly evaluated, or actualizes earlier extant evaluations. At the in the mean time closed BVWP of 1985, BVU was commissioned by the Minister of Transport to quantify and evaluate the effects of newly lines within the scope of a model simulation. A complex system of numerous detailed single models was developed to this effect and can be summarized in either following model step:

- Route searching in railway goods traffic: This step is a model simulation without capacity restriction. Under the assumption, that the existing network is sufficient to master the traffic demand, optimal routing following goods for railway goods traffic and the thence resulting network density are determined herewith. The result of this first model step is a density-capacity dependent ratio which indicates the underloading and overloading (bottle-necks) of the network.
- Traffic assignment and bottle-neck determination in the railway network: This step is a model simulation with capacity restriction. Here ensues the simulation of rerouting trains away from network bottle-necks on the basis of certain selective criteria; the simulation of removal of trains from bottle-neck lines which can no longer make a detour by re-routing; as well as, in conclusion, the simulation of delay times on account of above average density of line capacity; "consequential" delays are also ascertained which result from missed connections in the shunting yards.

2. ROUTE SEARCHING IN RAILWAY GOODS TRAFFIC

2.1 Operational procedures in railway goods traffic

The German Federal Railway gains with transport services in railway goods traffic more than half of its total receipts and accordingly its investive and operational efforts are intensively co-ordinated to further the transport share of the GFR in the goods transport traffic market vis-à-vis road transport of goods and inland navigation.

There exist two different operational procedures by the German Federal Railway for the seeing through of rail traffic. The use of so-called complete train-loads, as well as the so-called complete wagon-load method in single wagons or cut of wagons. By transported goods in complete train-loads it is primarily a question of heavy traffic conveyed in bulk as coal, coke, iron ore, steel, petroleum crude, petroleum products, lime, pebble stone and sand. These trains are usually formed ready for departure by the sender and are taken over by the consignee as a block train, en bloc. Analogous to road traffic these complete train-loads are sensibly transported along the least time and cost consuming route.

Contrary to complete train-load method by numerous transport situations by wagon-load traffic, the number of wagons in a marshalling yard is not sufficient to build a train which doesn`t stop to a specific destination marshalling yard. In these cases then, the wagons are shunted to other trains along fixed routes to other marshalling yards, which to some extent lie in the forseen routing on the flow of traffic. Depending on the distance, train availability and density of traffic such shunting is not at all necessary - not more than once or even once. Among the many possibilities which hereupon present themselves for routing-choice, the routing followed, well, analogous to complete train-load traffic, by complete wagon-load traffic thoughtfully be chosen between a forwarding and destination marshalling yard which exhibits the shortest total transport time between these stations, inclusive the necessary shunting-time. Routing is defined according to this by the starting marshalling yard; if the need arises by one or by several intermediate marshalling yards, the destination marshalling yard, as well as the least time consumming railway line connection between the respective stations. The simulation procedure for the optimization of routing (transport routes) in railway goods traffic is according to the following working order:

1. In a first step "route searching I" - in order to meaningfully get the model procedure in the first instance going, one starts form an imaginary operating method whereby all marshalling yards of the German Federal Railway network are linked with each other by through service, i.e. not necessitating a switching over of wagons at intermediate marshalling yards.

2. In a second step "train formation and train operation", the wagons are "fed" into the network and by simulation of train formation and operation a realistic train offering compilation and schedule calculation is constructed for the given wagon streams.

3. In a third step "route searching II" one does not determine as in the first step of the working order, on the basis of theoretical train connections between marshalling yards, but rather on the basis of realistically simulated trains, which train connections can transport goods wagons fastest and least costly from a forwarding to a destination marshalling yard and, if need arises on one or several intermediate marshalling yards switched over (routes followed).

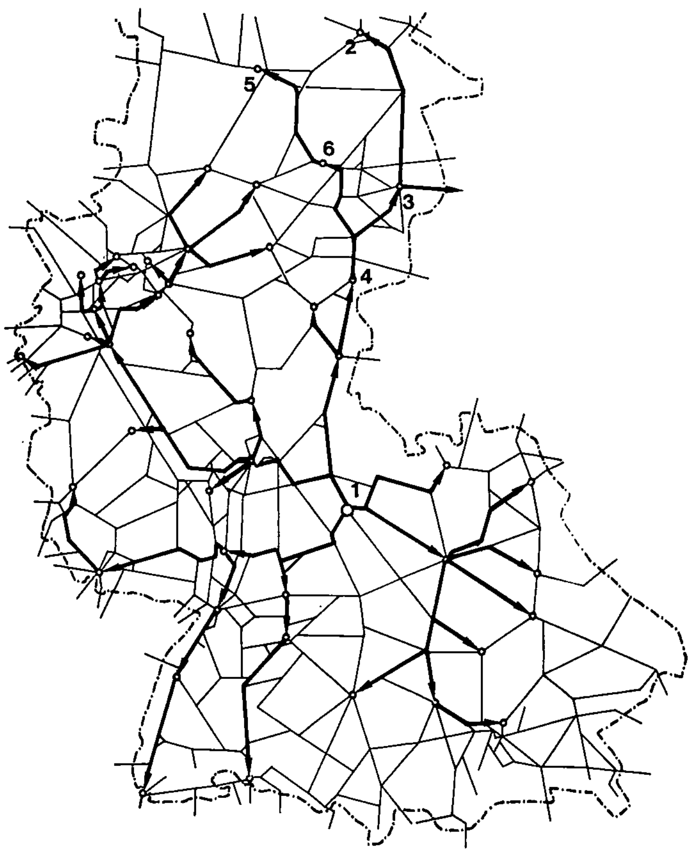
4. The second and third steps are to be respectively carried out at specific hours of day (interval). Thereby , the train offering compilation and the schedule calculation are successively improved. The procedure is repeated as long (number of intervals) till the train offering compilation and schedule compilation have been stabilized, i.e. no changes are undergone in the further intervals.

2.3 Simulation of train formation and train operation

The simulation of train formation in forwarding and intermediate marshalling yards as well as operation of trains between marshalling yards according to the actual operating method of the German Federal Railway displays without doubt the most complex operation within the entire model procedure of the determination of routes. Hereby, all marshalling yards of the network are "checked" one after another in each interval according to a previously fixed order. The most important piece of information for train formation in a specific marshalling yard are the so-called "route-trees", which contain all the best routes (least time consuming train connections) of the station being considered at the moment to all remaining marshalling yards of the network. An example of such a "routing-tree" for the network of the German Federal Railway is figure 1 which represents marshalling yard 1.

The operating method of the GFR is based upon the aim to handle as many as possible rail transports overnight, i.e. to deliver the consignee in the morning goods consigned to the GFR by the sender the evening before. This object in view was taken into account in the algorithmization, so that the "route-trees" - beginning with the destination marshalling yard for which the longest conveyance time is necessary - were, let us say, retrogressively "checked". Related to the "route-trees" included in figure 1, this eventually means, that to begin with, all waiting wagons with the destinations 2 form a train; if the number of wagons isn`t sufficient for a train formation, supplementarily to

Figure 1: Route trees in the railway network of the German Federal Railway for marshalling yard 1 (theoretical example)



wagons leading for destination 2, the wagon streams also for destination station 3 are marshalled. If by this retrogressive checking of the "route-trees" a branching out is reached (in the case under discussion the branching out between stations 3 and 4), the newly included branch with the stations 5 and 6 is now to be dealt with analogously, till finally the entire "route tree" has been checked.

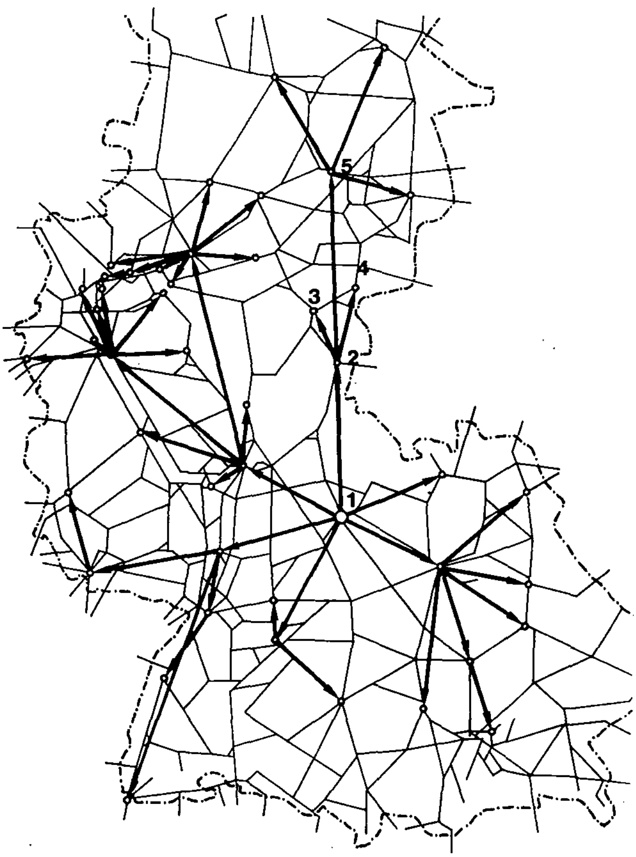
A significant control factor for the train building process is represented in the time between trains at the marshalling yard, which is defined by the time interval between the arrival of a reception and the departure of a departing train. The time between trains depends directly on the capacity of the marshalling yard being considered.

As soon as trains are formed with the prescribed load, they are placed in service. The departure time of these trains results from the time of arrival and the time between trains of wagon streams in a marshalling yard. At the destination station, the train being considered is then stored with all necessary information (wagon code, forwarding and destination marshalling yard, time of consignment dispatchment, etc.) for the in the next interval following train building procedure.

2.4 Route searching in the train network

The more intervals are checked, the more trains are brought into operation between the marshalling yards. Accordingly, the so-called train network thereby compresses which results of the third step of the working order (route searching II) and no longer of the actual route sections of the starting network (step 1),but rather is composed of the train connections between marshalling yards (figure 2). The route searching procedure in this train network accords to the joining of train connections between marshalling yards analogous to the search for the best time-table connections by passenger traffic. Applicable best routes are found in this procedure in the interval being considered at the moment, which can be composed of one, but by all means also of several trains. Hereby, in an intermediate marshalling yard wagons of an arriving train can always then be switched to a departing train, when between arrival and departure an equally large or larger time period than the specific time between trains is present, which was ascertained by the train formation for each individual interval in relationship to the number of waiting wagons and the capacity of the marshalling yard. Analogous to traditional route searching programmes in the road system, train transport time solely displays line resistances, the time necessary for train formation in the marshalling yards junction resistances.

Figure 2: Route tree in the train network of German Federal Railwy for marshalling yard 1 (theoretical example)



2.5 Frequency of simulation intervals

As already explained, step 2 (train formation and train operation) and step 3 (route searching II) in the working order are to be newly simulated in each time interval. Collectively the repetitive procedure is to be continued so long till the momentary best routes (routes followed) are found and don`t change any more. Applied to the constellation and the transport differences in the net of the German Federal Railway, there are accordingly at least 40 - 50 interval steps required in order to also document the reciprocal effects of the furthest far off from each other lying marshalling yards. Since the simulation procedure for each interval by the given network size (35 marshalling yards) needs only about 10 minutes of computation time on a medium scale computer (HP 1000), in the here represented routes followed optimization, the iterative procedure was expanded to about 500 intervals, in order to be sure. The intermediate results of the stored single intervals already show however that the heuristic method, long before the iteration programme has been run, the expected convergence and stabilization of the routes has been found. After 24 intervals already 36 %, after 48 intervals 81 % of the definitive routes have been found by this time; after the 456th interval no further change occurred in the routing system.

3. TRAFFIC ASSIGNMENT AND BOTTLE-NECK DETERINATION IN THE RAILWAY NETWORK

3.1 Route diversion of trains in the railway network

The decisive starting point for the planning of new lines in the German Federal Railway network are bottle-necks in the existing network, which are opposed to an optimal functioning of passenger and good traffic. In order to identify these network bottle-necks for once, it is necessary at first to leave out of consideration the ascertainment of optimal transport routes for railway goods traffic, so that all trains can travel on their best possible route.

When bottle-necks in the network have been realised and the magnitude of the overload on the line quantified on the basis of a load on a line-cpacity ratio, one will first try to drain off onto other extant line possibilities, a partial diversion of trains in the network travelling through the bottle-neck. The simulation of this route diversion ensues according to the following criteria:

- Only goods trains are diverted in the network since the routes of passenger trains through the relatively close succession of stations cannot at all be changed;
- the length of the deviation route must not exceed by more than 10 % the whole route, in order to prevent an uncontrolled "wandering about" of trains in the network;
- in order to achieve the biggest possible alleviation of bottle-necks with the diversion of a train, one began with the diversion of those goods trains which travel

through the most bottle-necks;

The relative time consuming simulation of diversion trains was solved in model in the way that in the existing network used as a print of departure, all bottle-neck-lines were eliminated and hereupon new best routes were ascertained. As soon as the train line carrying capacity on the deviation routes likewise reached the load limit, these lines were likewise eliminated in the model network and route searching was extended to 2nd and 3rd best deviation routes which still had unused reserve capacity.

3.2 Shifting of rail transports onto road traffic

After full utilization of all deviation posibilities in the rail network of the German Federal Railway there still remain a set of line sections, whereon, according to the model simulation, still more trains travel daily than the maximum line capacity allows. This line overloading cannot be activated at the moment because of the defective quality and capacity of the present rail network. In order to be able to quantify the loss of these transports for rail traffic in the retention case of the ascertained bottle-necks in the scope of an evaluation operation, one assumes at first, that they are shifted onto roads traffic. Just like by route diversion only goods transports were affected when shifting, while passenger traffic was handled and given in every respect priority. Furthermore, shifting, analogous to route diversion likewise followed the rule of precedence, shifting at first those trains onto roads traffic, which travel through the most bottle-necks, and with their shifting result in the greatest alleviation for the rail network. With the completion of such shifting, which is only theoretical and necessary for the evaluation as a reference value, all bottle-necks in the network have been eliminated.

4. APPLICATION AND USE OF THE SIMULATION MODEL

4.1 Evaluation of the newly-laid lines of the German Federal Railway

The models which have been described until now are part of an evaluative procedure which is based on the so-called "Federal Traffic Planning" of the Minister of Transport, which is regularly activated in cycles of 5 Years. In this evaluative procedure the economic cost-benefit analysis of the object under study-without evaluative means (base case) is compared to the costbenefit analysis of the object under study with evaluative means (on-line case). Base case and on-line case differ merely in the evaluative means; hence, in the present case, in regard to newly laid lines in the rail network. As already explained, the database for this evaluation consists primarily in the following model results:

- Routing followed and timetables for railway goods traffic which have been ascertained and optimized;
- decreasing the line load of the rail network by the

shunting of goods trains to routing followed or shifting of goods trains onto road traffic in case of rail bottle-necks.

The foremost influential factors for the optimization of routing and timetables in railway goods traffic consist of transport streams as well as the placement and efficiency of marshalling yards in the rail network. Today this optimization is a process which is realized yearly at the changing over of the time-table and occupies a significant number of experts of the German Federal Railway. The results of this process, which is still done "by hand", concur contextually and qualitatively almost totally with the results of model-like routing followed and timetable optimization.Decisive is hereby, however, that the optimization which was carried out without a model was only possible because it represents a procedure over many years, whereby one could build on the well-grounded point of departure, and by each optimization step only relatively small changes of the influential factors (number of marshalling yards, transport streams etc) had to be taken into consideration. A totally changed supply and demand situation of railway goods traffic, as somewhat encompassed in the "Federal Traffic Planing" for the forecast year 2000, model-like to simulate, could not have on the contrary, at all been solved with the present method of the German Federal Railway. In opposition to this the developed routing followed model has the ability to develop the appropriate routing followed and timetable constellations in a very short time and with relatively moderate costs for every kind of suppley and demand situation whatsoever. The optimization model has already been applied three times on behalf of the German Federal Railway in this context. An exemplary result of ascertained routing (followed) for a chosen marshalling yard is found in figure 3.
As already explained, train assignment onto the network, the second model step of the entire simulation, ensues for its part in the three following steps:

- Assignment of trains onto the network according to the routing followed defined transport routes; the result of this shunting manoeuvre is a mild overloading of the rail network, which in part includes overloading of the line (bottle-necks);
- Diversion of trains away from bottle-necks in the network; result of this step in the procedure is a train overloading situation after using all free capacities on lines which are possible diversion routes;
- Shifting of trains on line bottle-necks onto roads traffic; this "theoretical" shifting is cancelled after the bottle-neck has been eliminated by improvement or construction of new lines. Re-shifted goods traffic from roads traffic onto rail traffic comprised, in the most cases, the decisive advantage component by the evaluation of planned new lines of the German Federal Railway.

An estimative result of the shunting and diverting of trains in the rail network for a couple of chosen route

AUFKOMMEN (WAGEN)	ABF. (STD)	ANK. (STD)	QUELLRANGIERBAHNHOF	ZIELRANGIERBAHNHOF	UMSTELLBAHNHOEFE	
48			1 MASCHEN NORD-SUE	2 OSNABRUECK		
	9	19		2 OSNABRUECK	4 SEELZE WESTBERG	29 SEELZE OSTBERG
56			1 MASCHEN NORD-SUE	5 BRAUNSCHWEIG		
	0	9		5 BRAUNSCHWEIG	4 SEELZE WESTBERG	
	9	20		5 BRAUNSCHWEIG	4 SEELZE WESTBERG	
73			1 MASCHEN NORD-SUE	6 HAMM OST-WEST		
	19	2		6 HAMM OST-WEST	30 HAMM WEST-OST	
	23	8		6 HAMM OST-WEST	30 HAMM WEST-OST	
	4	11		6 HAMM OST-WEST	30 HAMM WEST-OST	
	9	20		6 HAMM OST-WEST	4 SEELZE WESTBERG	30 HAMM WEST-OST
18			1 MASCHEN NORD-SUE	7 HG-VORHALLE		
	16	1		7 HG-VORHALLE	6 HAMM OST-WEST	
	4	14		7 HG-VORHALLE	30 HAMM WEST-OST	6 HAMM OST-WEST
	6	23		7 HG-VORHALLE	31 GREMBERG S-N	12 GREMBERG N-S
31			1 MASCHEN NORD-SUE	8 WANNE		
	15	1		8 WANNE	30 HAMM WEST-OST	
	21	6		8 WANNE	30 HAMM WEST-OST	
	23	10		8 WANNE	30 HAMM WEST-OST	
	4	15		8 WANNE	30 HAMM WEST-OST	
	9	22		8 WANNE	4 SEELZE WESTBERG	30 HAMM WEST-OST
	13	24		8 WANNE	12 GREMBERG N-S	
56			1 MASCHEN NORD-SUE	9 OBERH WEST		
	16	2		9 OBERH WEST	6 HAMM OST-WEST	30 HAMM WEST-OST
	6	19		9 OBERH WEST	31 GREMBERG S-N	12 GREMBERG N-S
	9	22		9 OBERH WEST	4 SEELZE WESTBERG	30 HAMM WEST-OST
31			1 MASCHEN NORD-SUE	10 DU-WEDAU		
	13	1		10 DU-WEDAU	12 GREMBERG N-S	
	16	2		10 DU-WEDAU	6 HAMM OST-WEST	30 HAMM WEST-OST
	18	5		10 DU-WEDAU	30 HAMM WEST-OST	
	4	17		10 DU-WEDAU	30 HAMM WEST-OST	9 OBERH WEST
	6	21		10 DU-WEDAU	31 GREMBERG S-N	12 GREMBERG N-S
	9	23		10 DU-WEDAU	4 SEELZE WESTBERG	30 HAMM WEST-OST
19			1 MASCHEN NORD-SUE	11 AACHEN		
	13	1		11 AACHEN	12 GREMBERG N-S	
	19	7		11 AACHEN	31 GREMBERG S-N	12 GREMBERG N-S
	21	10		11 AACHEN	30 HAMM WEST-OST	8 WANNE
	23	21		11 AACHEN	10 DU-WEDAU	
	4	23		11 AACHEN	30 HAMM WEST-OST	8 WANNE
5			1 MASCHEN NORD-SUE	12 GREMBERG N-S		
	19	4		12 GREMBERG N-S	31 GREMBERG S-N	
	21	12		12 GREMBERG N-S	4 SEELZE WESTBERG	31 GREMBERG S-N
	6	16		12 GREMBERG N-S	31 GREMBERG S-N	

Figure 3: Routing and timetable for a chosen marshalling yard

sections (origin and destination junctions) is shown in figure 4. According to this, the model result for each route section and route destination is characterized by the following pieces of information

- Number of daily passenger trains in short-distance (NAH) and long-distance (FERN) traffic;
- Number of daily goods trains between satellite and junctions stations (UG), between junctions stations and marshalling yards (NG), between marshalling yards (DG) as well as complete train-loads (GANZ), which travel as a train-bloc between senders and consignee without any intermediate handling (shunting at marshalling yards);
- Number of remaining goods trains (e.g. light running);
- required line capacity based on the ascertained train load on the line;
- Extant line capacity;
- Unused line capacity (positive value) or line bottle necks (negative value).

As already mentioned, after completion of the second step not only the estimative information concerning the capacity use of route sections are at hand but rather the intermediate result of the model procedure are detailed information is present about each train on a journey regarding forwarding and destination station, train type, train load, including forwarding and arrival station of each wagon in these trains. Only because of this detailed information was an exact evaluation possible orienting the actual operation of the German Federal Railway in railway goods traffic, whereby the consequences of the train diversion (delays and deviations in contrast to the normal situation) as well as the shifting of trains (wagons in a train which is shifted,for their part, are shifted for their entire transport route).

In the scope of Federal Traffic Planning, the second step of the model has been applied collectively to 27 different planning cases (projected new lines in the network of the German Federal Railway).

4.2 Other application to special cases

The German Federal Railway has in the course of recent years continuously reduced the number of marshalling yards in its network from circa 45 to 27 at present. This process is being continued and could by all plans in the future terminate with a maximum number of 20 marshalling yards. The positive consequence of this reduction has been, that among the remaining marshalling yards much more goods train through service (i.e. no shunting at a intermediate marshalling yard) could be offered because of the concentration of transport streams.

The first model step for the optimization of routing followed and time tables in railway goods traffic is exeptionally suited to accompany this reduction process and to

STARTKNOTEN	ZIELKNOTEN	PERSONENVERKEHR NAH	PERSONENVERKEHR FERN	PERSONENVERKEHR GESAMT	----GUETERVERKEHR---- UG	NG	DG	GANZ.	GESAMT	SONST. VERKEHR	GESAMT- VERKEHR	ERFORDERL. LEISTUNGSF	STRECKEN- LEISTUNGSF	FREIE LEISTUNGSF
1 MASCHEN NORD-SUE	28 MASCHEN S-N	26	39	65	4	26	79	13.7	122.7	16.9	204.5	223.3	238.0	14.7
28 MASCHEN S-N	1 MASCHEN NORD-SUE	26	39	65	4	111	18	19.9	152.9	19.6	237.5	259.2	274.0	14.8
1 MASCHEN NORD-SUE	81 HMB-HARB	26	40	66	4	113	15	19.9	151.9	43.6	261.4	283.2	274.0	-9.2
81 HMB-HARB	1 MASCHEN NORD-SUE	26	40	66	4	86	21	13.7	124.7	38.1	228.8	247.8	238.0	-9.8
28 MASCHEN S-N	79 BUCHH (NH)	0	0	0	4	2	36	2.9	44.9	4.0	49.0	53.5	144.0	90.5
79 BUCHH (NH)	28 MASCHEN S-N	0	0	0	4	2	52	5.2	63.2	5.7	68.8	75.2	169.0	93.8
28 MASCHEN S-N	1024 WINSEN	26	40	66	4	2	41	10.7	57.7	11.1	134.9	147.2	163.0	15.8
1024 WINSEN	28 MASCHEN S-N	26	40	66	4	32	25	14.7	75.7	12.8	154.5	168.7	163.0	-5.7
36 HMB-ROTH	78 BUECHEN	25	12	37	4	5	28	14.9	51.9	8.0	96.9	105.8	999.0	893.2
78 BUECHEN	36 HMB-ROTH	25	12	37	4	0	6	12.1	22.1	5.3	64.4	70.3	999.0	928.7
36 HMB-ROTH	85 HMB SUED	0	0	0	4	31	10	16.8	61.8	12.4	74.2	80.4	84.0	3.6
85 HMB SUED	36 HMB-ROTH	0	0	0	4	40	29	20.1	93.1	18.6	111.7	121.0	84.0	-37.0
36 HMB-ROTH	1007 HAMBURG HBF	25	12	37	4	0	0	0.0	4.0	3.7	44.7	48.8	108.0	59.2
1007 HAMBURG HBF	36 HMB-ROTH	25	12	37	4	0	0	0.0	4.0	3.7	44.7	48.8	108.0	59.2
36 HMB-ROTH	1009 ABZW. HAMBURG	0	0	0	4	25	5	4.4	38.4	3.5	41.9	45.7	58.0	12.3
1009 ABZW. HAMBURG	36 HMB-ROTH	0	0	0	4	25	3	3.8	35.8	3.2	39.0	42.6	58.0	15.4
38 BAD OLDESLOE	1009 ABZW. HAMBURG	65	28	93	4	25	3	3.8	35.8	11.6	140.4	153.2	999.0	845.8
1009 ABZW. HAMBURG	38 BAD OLDESLOE	65	28	93	4	25	5	4.5	38.5	11.8	143.3	156.4	999.0	842.6
49 HMB-ALT	51 HMB-EID	66	36	102	4	29	2	4.2	39.2	28.2	169.4	183.6	170.0	-13.6
51 HMB-EID	49 HMB-ALT	66	36	102	4	31	0	2.8	37.8	28.0	167.8	181.8	170.0	-11.8
49 HMB-ALT	1007 HAMBURG HBF	20	25	45	4	34	2	2.8	42.8	17.6	105.4	114.2	198.0	83.8
1007 HAMBURG HBF	49 HMB-ALT	20	25	45	4	33	2	4.2	43.2	17.6	105.8	114.7	198.0	83.3
51 HMB-EID	55 ELMSH	66	36	102	4	26	2	4.2	36.2	12.4	150.6	164.4	170.0	5.6
55 ELMSH	51 HMB-EID	66	36	102	4	28	0	2.8	34.8	12.3	149.2	162.8	170.0	7.2
51 HMB-EID	1009 ABZW. HAMBURG	0	0	0	4	0	0	.0	4.0	.4	4.4	4.8	58.0	53.2
1009 ABZW. HAMBURG	51 HMB-EID	0	0	0	4	0	0	0.0	4.0	.4	4.4	4.8	58.0	53.2
79 BUCHH (NH)	81 HMB-HARB	28	39	67	4	0	0	0.0	4.0	6.4	77.4	84.5	160.0	75.5
81 HMB-HARB	79 BUCHH (NH)	28	39	67	4	0	0	3.0	7.0	6.7	80.7	88.1	160.0	71.9
81 HMB-HARB	84 HMB-WLB	56	85	141	4	102	18	24.1	148.1	57.8	347.0	375.9	312.0	-63.9
84 HMB-WLB	81 HMB-HARB	56	85	141	4	77	19	12.7	112.7	50.7	304.4	329.8	330.0	.2
81 HMB-HARB	1012 BUXTEHUDE	35	0	35	4	5	0	.1	9.1	4.0	48.1	52.5	101.0	48.5
1012 BUXTEHUDE	81 HMB-HARB	35	0	35	4	5	1	3.2	13.2	4.3	52.5	57.4	101.0	43.6

Figure 4: Overloading of rail lines after diversion of trains away from bottle-necks

substantiate it with computative results thereby, and other marshalling yard is succesively eliminated each time and the pertaining data set of routing followed and timetable is ascertained. By comparing the computative results on the basis of different times needed for transports in the entire network, the forwarded distance (kilometric performance) as well as the number of necessary trains one can decide which marshalling yard can be eliminated with the least cost and greatest gain.

A further very interesting and promising range of application for the model simulation of routing followed is the optimization of the conveyance of train of empties, which must be brought from their unloading yard to their next loading yard. This area, where very apparently very large rationalization possibilities lie, is being researched by the BVU on behalf of the German Federal Railway; the related research work is however in the incipient stage.