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NARROW-GAUGE RAILWAYS FOR MILITARY PURPOSES.

Translated from "Revue Militaire de l'Etranger," April, 1894,

BY

LIEUT. E. H. M. LEGGETT, R.E.

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ERRATUM.

PAGE 2.—The gauge of the Austrian Railways is 70 c.m., as stated on page 20, and not 60 c.m., as on page 2.

PAGE 19.—*Fig.* 9 is printed upside down.

THERE is no necessity nowadays to insist upon the importance of field railways in war; but while all are agreed in principle, there are still differences of opinion as to detail, and the Continental armies, with their usual attention to minutiæ, have evolved various systems which they consider best suited to their several requirements. It is believed that a concise account of these has not before been placed at the disposal of the Corps of Royal Engineers, and accordingly a translation of an exhaustive article upon the German and Austrian systems which recently appeared in the *Revue Militaire de l'Etranger* is here subjoined; while I propose to briefly supplement this paper with a few remarks, for comparative purposes, on the French system. In the absence of any experience in war of these field railways, the results of their trial in manœuvres are briefly alluded to. I think that it cannot be denied that the importance attached to this special branch of engineer work abroad is nothing short of enormous, and this is perhaps the more significant when it is borne in mind that

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PREFATORY NOTES BY THE TRANSLATOR.

THE MILITARY FIELD RAILWAYS OF THE CONTINENTAL ARMIES.

THERE is no necessity nowadays to insist upon the importance of field railways in war; but while all are agreed in principle, there are still differences of opinion as to detail, and the Continental armies, with their usual attention to minutiæ, have evolved various systems which they consider best suited to their several requirements. It is believed that a concise account of these has not before been placed at the disposal of the Corps of Royal Engineers, and accordingly a translation of an exhaustive article upon the German and Austrian systems which recently appeared in the *Revue Militaire de l'Etranger* is here subjoined; while I propose to briefly supplement this paper with a few remarks, for comparative purposes, on the French system. In the absence of any experience in war of these field railways, the results of their trial in manœuvres are briefly alluded to. I think that it cannot be denied that the importance attached to this special branch of engineer work abroad is nothing short of enormous, and this is perhaps the more significant when it is borne in mind that the campaigns for which the Continental armies are trained will take place in a theatre of war well provided with road and railway communications of a permanent character. Any refusal to avail themselves to the fullest extent for military purposes of the means which modern mechanical science provides would be considered by the military powers of the Continent unjustifiable and almost criminal.

It may be well to mention that the questions of the location of main strategic lines of railway, and the working in war of these and other existing railways, either in their own country or as captured from the enemy, is considered abroad as a separate matter (from an engineer's point of view) from the laying and working of the temporary field railways in the theatre of war. The former and larger question, of course, has its correspondingly large influence on the strategic plan of campaign; and it may be said that, while the armies follow the main lines, the field lines follow the army. The former are "grande stratégie," the latter "minor tactics." It is with the field lines only that the present paper is concerned.

French Field Railways.

The French have adopted for field use a light railway of 60-cm. gauge, which it will be noticed is identical with the gauge of the German and Austrian systems. Like their neighbours, they have sacrificed much to portability and rapidity of construction, and in the absence of other information we must conclude that they intend to use their lines in the same way, namely, to follow an army in the field and keep it in touch with the nearest main line station, and so with the base. The somewhat lighter type of French plant is perhaps due to the fact that their possible theatre of war is better supplied with roads and railways (requiring, therefore, less use of military lines) than in the case of Germany or Austria, who might have to operate on their eastern frontier in a district comparatively bare of those means of communication.

General Type.—The material is that generally known as Décauville pattern, as illustrated in the catalogue of that firm. The permanent way is made in bays of fixed lengths, and the rolling stock is based on a single bogie unit of simplest possible construction, which can be made up into more complicated wagons and cars as desired.

The following is a fairly complete detail:—

Rails.—Steel, flat-footed; height, 6-cm.; flange, 6-cm.; web, 6-mm.

It will be noticed that this is one of the Sandberg standard sections, and can always be obtained in the market.

Sleepers.—Steel, trough section. This sleeper is hardly strong enough for heavy traffic, having a tendency to cross-break. The width is only 12-cm. They are generally spaced at 2-foot 3-inch centres. The rails are permanently riveted to the sleepers.

Bays, consisting of two rails and varying number of sleepers, according to length, are made up in lengths of 5-m., 2.50-m. and 1·25-m. They are connected up by means of two fish-plates at each joint, which are carried permanently bolted on to one end of the rails. The other ends, therefore, engage with the plates of the next bay. The joints are made on a sleeper, and are not suspended.

Locomotives are of the Fairlie type, called in France "locomotive jumelle," and in Germany "Zwilling's lokomotif." This type has been adopted by all foreign armies, and appears to be the only one which can obtain the necessary adhesion to fully utilize its tractive power. Certainly the loads taken by these engines up severe gradients are surprising.

Rolling Stock is entirely made up of small four-wheel bogies with a central pivoted bolster. The bogies can be used singly, in which case the load is 5 tons, or can be built up in a similar manner to the German stock described in the translation. Double bogie wagons thus formed carry 9 tons. Each bogie is provided with springs and brake.

Laying the Line.—As with the Germans, little or no preparation of the ground is anticipated, and the line will be as far as possible laid along the side of the roads.

The French do not appear to have worked out such a complete system as the Austrians for the laying of their line and providing for general transport simultaneously with railway construction traffic to a constantly extending railhead. This, if correct, may be accounted for by the lesser length of their probable lines.

Railway Training and Manœuvres.

Most Continental armies make field railways an important feature of their annual manœuvres, recognizing, with Major Tilschkert (of the Austrian Engineers), that the construction of a field railway cannot be undertaken with inexperienced men, and that the only way to attain the desired result in war is to adopt a system and practise it well in peace. When the troop cars, horse boxes, etc., to say nothing of the general system of traffic working, all differ from those which obtain on ordinary railways, it is evident that not only the technical troops who construct and work the lines, but also those who are to use them, must learn much from an intelligent training under service conditions.

Some idea of the completeness of these exercises will be obtained from the following examples :—

German Manœuvres, 1892.

In connection with these manœuvres the following railway troops were exercised, viz. :—

4 Traffic Companies. Railway Brigade.
4 Workmen Companies. Railway Brigade.
1 Construction Company. Bavarian Battalion.

The total strength of the German railway troops is as under (*vide Armed Strength*, 1892 edition) :—

	Officers.	Medical Officers.	Officials.	N.C.O.'s and Men.
Railway Brigade :—				
8 Construction Companies ...	72	8	8	1998
16 Traffic Companies	96	—	—	3296
4 Workmen Companies... ...	8	—	—	808
Total	176	8	8	6102
Bavarian Battalion :—				
1 Construction Company ...	9	1	1	222
2 Traffic Companies	12	—	—	412
1 Workmen Company	2	—	—	202
Total	23	1	1	836

As the troops employed in the manœuvres were brought up to war strength for the purpose, it will be seen that the following number of officers and men was engaged, viz. :—

	Officers.	Medical Officers.	Officials.	N.C.O.'s and Men.
Traffic Companies	24	4	4	832
Construction and Workmen ...	17	1	1	1030
Total	41	5	5	1862

The manœuvres were held near Uelzen, the junction of the Magdeburg-Bremen and Hanover-Hamburg main lines.

The depôt was fixed at Uelzen.

A field line was constructed from Uelzen to Celle 70 kilomètres, or about 44 miles, in length. It is interesting to note the number of men per mile works out to—

Construction	23 men,	0·38 officer.
Traffic (including loco.)	19 ,,	0·54 ,,

It is not apparent whether the construction gangs were utilized for maintenance purposes during the working of the line, or whether they were considered as being available for other work on completing the laying of the line. As will be seen from the detail given below, each traffic company possesses a certain proportion of platelayers, but it is doubtful if these undertake the entire maintenance of the division (being, as they are, less than two men per mile), or whether they are merely intended to act as watchers of the line and to guide the gangs which would be detached from one of the construction companies to carry out repairs. It is undeniable that very great advantage attaches to such a system on a military line (opposed though it is to civil practice) whereby the large gangs are not broken up along the line, but are kept in hand at one or more central points in the division and detailed by the officer in charge of permanent way for specific work, in much the same manner as are the large relaying gangs on our English railways.

It would appear that the whole railway on these manœuvres was divided into four sections of about 11 miles in length, each being worked by a separate traffic company. These sections seem to be very short, but the traffic was probably very dense.

It will here be of interest to give the railway detail of one of these companies.

Rank.	Number.	Railway Duty.
Officers :—		
Captain	1	Special duty.
1st Lieutenant	1	
2nd Lieutenants	4	Station Masters.
N.C.O.'s :—		
Sergeant-Major	1	—
Under Officers	40	4 Assistant Station Masters. 1 Baggage Clerk. 12 Engine-drivers. 7 Guards. 7 Brakesmen. 6 Telegraph Clerks. 3 Telegraph Line Inspectors.
Lance-Corporals	20	3 Guards. 1 Foreman of Telegraphs. 2 Foremen of Platelayers. 12 Locomotive Firemen. 2 Stationary Engines.
Men :—		
Privates	139	4 Shunters. 18 Signalmen. 14 Platelayers. 7 Engine-fitters. 4 Greasers. 2 Carriage Cleaners. 55 Porters. 35 Brakesmen.

The establishment of signalmen would apparently point to a length of almost 2 miles for the block sections, assuming 8 hour reliefs and a day and night traffic. There is, of course, no particular virtue about this distance, which would doubtless be increased on a longer line. Assuming the German military speed of 18 kilomètres per hour, however, it will be seen that the number of drivers and firemen is not enough to fill the line to its fullest capacity for more than 15 hours out of the 24. This figure is too significant to be accidental, and seems to point to a time table for German military lines of about 10 trains daily in each direction between 5 a.m. and 8 p.m., or roughly a daily capacity of about 1,200 tons of stores (or a corresponding passenger traffic) in each direction. (The supply of one army corps).

The stations were established about every $2\frac{1}{2}$ miles. The large station staff deserves notice, including as it does nearly a dozen trained porters per station, and probably a very much larger number at the termini. It is apparently recognized by the Germans that the proper stowing of stores in railway wagons requires attention from experienced men, and that this duty should not be left entirely to ordinary fatigue parties. In this connection it is worth mentioning that the proportion of skilled "packers" to ordinary labourers in an English railway goods shed is about one to four.

It is not quite evident on what system the laying of the line was carried out, but it was probably one of the two described in the translation below. The time taken to lay the 70 kilomètres was 9 working days, or $6\frac{2}{3}$ kilométres per day. As construction was not continued at night, this gives very nearly the speed claimed in the *Revue Militaire*, though the strength of the working parties is greater than there stated as necessary.

After construction, traffic working and maintenance were continued for $2\frac{1}{2}$ weeks, after which dismantling occupied one week.

This account of the German railway manœuvres is necessarily incomplete, but such as it is, I venture to think that it shows a state of technical training and organization (due to a full appreciation of the military value of field railways) which has not a parallel in Europe.

Austria and Russia.

The Austrians also possess a material and organization but little differing from that of Germany, but their annual training, conducted at Korneuborg, is on a more restricted scale than the above.

Large depôts of field railway material are collected by Russia in her frontier fortresses, and a portion of this is used for practice every year.

France.

In 1894 a very complete trial of the railway material described at the beginning of this paper was made by the French army in the fortress manœuvres near Paris. Some 30 kilomètres of line was laid, and traffic was worked over it during the operations. Perhaps the most instructive feature was the subdivision of the work between the artillery and engineers, the former claiming right to lay the lines in and near their batteries. Owing to some misunderstanding, it was found on the first day of traffic that no connection had been made between these sections, and some delay was caused while the gap was being made good. The lesson is, perhaps, not inapplicable to other branches of railway working, notably the traffic, in which any interference may well prove fatal. For example, any failure between those who load the wagons (fatigue parties) and those responsible for traffic movements (the engineers) may entirely wreck the system. Without entering into details, it may be added that such cases are not unknown.

The Madagascar Campaign.

With large stores of military railway plant, and an establishment of railway troops anxious to make use of their knowledge, it was natural that much should have been said on the railway question while the arrangements of the Madagascar campaign were in progress. The *Avenir Militaire* made itself the spokesman of the technical troops, and was ably seconded by the *Journal des Travaux Publics.* The object being one of permanent occupation, it was pointed out that organization of communications must form the very basis of a peaceful settlement of the island. The distance between Majunga and Antananarivo is only 286 kilomètres, or less than 180 miles, and a daily rate of progress of only 2 kilomètres would have seen the railway at the latter place in less than five months. The troops would be supplied on the march, and much discomfort and disease would be obviated. In conclusion, said the *Avenir Militaire,* the railway line would be consolidated and strengthened, and would form a permânent communication between the capital and the sea, and, as such, a material guarantee of peace. Unfortunately, these arguments, or rather their converse, came only too true, and the graves which mark the line of advance of the French troops, and the revolution with which they are now face to face in the island, are eloquent testimony to the foresight of the *Avenir*.

The railway was strenuously opposed by General Villenoisy, who pointed to the want of success and enormous cost attending the similar lines constructed, or rather attempted, in the Senegambia campaign, and to the utter failure of the Décauville plant when tried between Soussa and Kairouan in 1883. Villenoisy triumphed, and no railway was attempted.

We have then before us the principles which guide Continental armies in the matter of field railways, and we have the result of their trials in peace; but, so far, the problem remains unproved in war.

E. H. M. Leggett, *Lieut., R.E.,*
Traffic Manager, R.A. Railways.

September 20*th,* 1896.

TRANSLATION.

In view of the important *rôle* which railways will be called upon to play in future wars, every nation has been obliged to construct for itself a railway system corresponding to its plan of defence, but out of all proportion to the requirements of the country in time of peace. The various Governments have been, therefore, driven to build these lines themselves, or, by means of subsidies and guarantees of interest, to assist private enterprise in their construction. Financial charges having been thus materially increased, it can be understood that, wherever possible, every effort has been made to economize in the outlay on railway construction.

This necessity for economy has thus given rise to a system of "narrow-gauge" railways, whose chief points of difference from normal lines is expressed by this description. By reducing the gauge of the line, it is possible at once to lighten the rolling stock, to simplify the construction of permanent way and station buildings, and to select a route more in agreement with the natural features of the country; thus to an appreciable extent diminishing the cost of construction and maintenance.

It is proposed, in the following pages, to study briefly the principles adopted abroad (*i.e.*, out of France.—E.H.M.L.) for the construction and working of narrow-gauge railways; and, finally, to enquire into the services such lines may be called upon to perform in war, whether constructed at leisure in time of peace, or laid as required during a campaign for the purpose of assuring the supplies of an army.

Determination of Gauge.

As stated above, the reduction in gauge is able to conduce to economies of such importance as to render profitable the working of a line which, if of normal gauge, would be unduly costly. This saving is spread over two classes of expenditure, viz.: (1), construction, or initial outlay; (2), maintenance and working expenses. As regards the initial outlay, we find that a reduced gauge implies smaller and lighter rolling stock, and consequently lighter and less costly materials, such as rails, sleepers, chairs, etc. From the military standpoint, this reduction in weight has another and greater advantage, that of portability, the importance of which will appear later. The reduction in length of rolling stock allows also of sharper curves, which consideration brings us to the advantage, military and economical, gained by conformity to the contour of the ground. To a large extent, therefore, engineering works can be avoided the construction of which in the field would be frequently impossible by reason of the time required.

Absolute rules as to gauge cannot be laid down. In the case of permanent lines, each case must be decided upon after consideration of the amount of traffic which the line may be expected to serve. In the case of field military railways, a minimum gauge must be adopted, with a view to the weight, and consequent portability, of the various materials. After an exhaustive series of comparative trials with different systems, carried out during the last few years by the German Railway Brigade, the 60-c.m. gauge has been adopted by that country as satisfying all the conditions necessary for field service. It appears, moreover, that in Germany this gauge will in future be imposed upon all concessionaries for new light railways. It is stated by the *Kölnische Zeitung* that the Minister of Public Works has decided that, for strategical reasons, the new narrow-gauge lines in Silesia are to be of this gauge. With this decision the German journal disagrees, considering it a matter for regret that a permanent line should be condemned to the disadvantages inseparable from a temporary field railway ; and it is certainly undeniable that the latter will be required to carry out a very different service to that of the former. While the premier consideration, in the case of the military line, is that of rapidity of construction, the permanent railway aims first at a maximum carrying power ; and though lightness and simplicity of material and equipment are matters of the greatest importance to the German, these assume a secondary position on a commercial undertaking. It is certain that if the military gauge be generally enforced for private railways, some of these will be placed in such a position as to render their working unprofitable. The correspondent of the *Kölnische Zeitung* is, then, right in deploring the imposition of the 60-c.m. gauge on all companies who may desire concessions for light railways in Silesia ; but he forgets, or ignores the fact, that in Germany military considerations invariably rank before private interests. The obvious military advantage of this arrangement lies in the fact that the possibility of requisitioning the material of private companies for military purposes is assured to the State, which can thus dispense with any large accumulation of material in time of peace, certain as it is of finding all that it requires on mobilization.

German Military Railways.

Following on the experience of the Railway Brigade, the following principles of construction, etc., for military narrow-gauge railways, have been formulated in Germany.

Gauge.—A gauge of 60-c.m. is considered sufficient for military purposes. Apart from pecuniary reasons, this gauge can be laid on roads, without interference with the ordinary traffic; and it can also be laid on curves of small radii and on severe gradients. The importance of the latter is apparent when comparing commercial and military lines.

Plan and Section.—Experience shows that a curve of 30-m. radius is the least that can be employed on any line of 60-c.m. gauge worked by locomotives. For curves of lesser radii, the locomotive must be more complicated, and consequently more costly; and it must be borne in mind that the friction increases inversely as the radius of the curve. The fixed wheel base of rolling stock is calculated to admit of a 10-m. curve; and it is possible to pass private companies' (narrow-gauge) wagons on to military lines.

Taking the average weight of a train at from 60 to 70 tons, the determination of the longitudinal section of the line presents the following points:—

Gradients less steep than 1 in 50 present no inconvenience, and need not interfere with the regularity of the train service. On grades between 1 in 40 and 1 in 50 of a greater length than 400 to 500 mètres, intermediate lengths of level line should be provided of a length double that of the train. Gradients steeper than 1 in 40 are avoided, as far as possible, in the interests of the regularity of train service, and banking engines are necessary when the grade is longer than 300 mètres. Similarly for grades of 1 in 30 and 1 in 25 when the length exceeds 200 and 100 mètres respectively. Gradients of 1 in 18 can only be passed when not exceeding the length of the train, and when the latter can get a "run" at the bank.

All sharp changes of grades are avoided, and grades should be straight as far as possible. When the line is at the same time on curve and gradient, the latter must not be more than 1 in 60, and the radius of the curve 200 mètres or more; while portions of line leading to a grade of this kind should also not be on a curve of less than 200-m. radius.

Permanent Way.—A solid formation and well ballasted permanent way have great advantages as regards passage of traffic and facility of maintenance. On embankments, the formation should be sufficiently wide to obviate any fear of collapse due to slipping of the side slopes.

To diminish the cost of construction, existing roads are utilized as much as possible; but it is obvious that considerations of economy would have no weight when building lines in the course of a campaign.

Rails, Sleepers, etc.—For locomotive traffic, a flat-bottomed rail, weighing 9·5 kilogrammes per mètre, is found best. This rail is 7-c.m. high, 5-m. long, and is designed to offer a large surface to the tread of the wheel.

Sleepers 1·20-m. long, 140 to 160-m.m. in width; spaced at intervals ·65-c.m. to ·75-c.m. They are of iron or wood. The joints are opposite one another, and connected by fish-plates or angle irons with four bolts.

When well ballasted, a line laid on this system will satisfy generally the requirements of military service; but if to be subjected to very heavy traffic, the line must, of course, be strengthened further.

Locomotives.—The maximum work for minimum weight is obtained from a 6-wheel coupled engine of Fairlie type, which has been successfully tried on various narrow-gauge lines, particularly on the 70-c.m. line between Brod and Sarajevo in Bosnia.

Boilers are tested to 20 atmospheres with a maximum working pressure of 15 atmospheres. The weight of the locomotive in running order is 15 tons, with a tractive power of 2 tons.

As regards the loads taken on inclines, experience shows a power of taking 120 tons up a grade of 1 in 100, following to 30 tons on an incline of 1 in 25. These figures can, however, be materially increased by the skill of the driver, or when the incline can be taken with a rush or temporary increase of pressure.

The consumption of coal varies from 125 to 200 kilogrammes per hour, and of water 600 to 900 litres per hour, according to load, speed and gradient. The locomotive can carry sufficient water and coal for 2 to 2½ hours' run; and except for very long journeys, a tender is considered unnecessary.

Locomotives are fitted with pulsometers for drawing water from below the level of the boiler; the latter being supplied from a saddle tank.

Wagons.—The best results are given by the bogie type. The system decided upon is that of a free central pin on each bogie, on which the underframing supporting the body of the wagon can turn. The underframing can, if necessary, be replaced by a cross bar when carrying undressed logs, long bars of iron, or heavy guns. With two bogies a wagon can be constructed to carry 5,000 kilogrammes, with a capacity of 6·3-c.m. Wagons must be fitted with proper draw bars, spring buffers, and a safe and powerful brake. Though the price of the wagons is increased by these additions, the regularity of the running is thereby assured.

Dimensions are as follows :—

Diameter of wheels	0·45 mètre.
Wheel-base	0·70 ,,

Flanged are preferable to grooved wheels, as being less liable to risk of derailment. Grooved wheels should only be employed when the rail is too light for its work, with consequent danger of "splitting the gauge." They add considerably to the friction, and can only roll on a rail of standard dimensions. Points and crossings become very complicated when this form of wheel is used.

Passenger Vehicles.—The 60-c.m. gauge is well suited to the requirements of passenger traffic; the vehicles experimented with being fitted with longitudinal seats (as on tramcars) and capable of carrying 20 men per car. The seats are mounted on springs, to lessen shocks and give smooth running on an inferior line.

General Remarks.

The above are the principles followed in Germany in the construction of narrow-gauge railways worked by locomotive power. It is obvious that these lines can only be constructed under certain conditions of trace, profile, and solidity, incompatible with hasty work, and impossible to attain when keeping up with an army on the march, for the construction of such a line would be too slow to be able to follow the troops at any useful interval.

The opinon of an Austrian officer, Major Tilschkert, is as follows :—"Narrow-gauge railways worked by locomotives require too much time for construction, and cannot serve an army in the field. The line from Brod to Lenica, 190 kilomètres in length, of 70-c.m. gauge, was not completed for nine months. The total length of embankment was about 121 kilomètres and of cutting 10 kilomètres. 36 bridges, with a total length of 1,668 mètres (nearly one mile), were also required. In 1880, the 12 trains travelling daily in each direction represented a total weight moved of 324 tons, but this load on a tramway would only require 100 horses and 100 wagons. A line, however, worked by locomotives would always have the advantage of speed over a tramway worked by horses.

It must be added that the weight of the material required for the line itself is no small quantity. The German line weighs about 33 kilogrammes per mètre run; and for 15 kilomètres of line it would be necessary to transport about 500 tons of rails, sleepers, etc., not including the ballast, which is indispensable, and can but rarely be found near the spot. To this dead weight add that of the rolling stock at 10 tons per locomotive and $1\frac{1}{2}$ tons per wagon for a total required of 10 engines and 150 wagons, adding up to 320 tons, which brings up the whole load which must be transported to 820 tons for 15 kilomètres.

Field Railways.

To secure for an army in the field the advantages of railway transport, the locomotive must be replaced by some other means of traction, allowing of a more simple road, and one more quickly laid. A great number of experiments have been carried out in Austria and Germany, and these countries have decided upon a lighter and more flexible line, more elementary in every sense, to be worked either by manual or by horse labour, and apparently suited to all the requirements of supply of an army on the march.

The calculation of the carrying power of such a line is not a difficult matter. Denoting by P the weight to be transported, it is found that the power necessary to draw this load is:—

(1). On rails ... ... = ·006 P.
(2). On good road ... ... = ·03 P.
(3). On bad road ... ... = ·1 P.

Traction on rails, therefore, requires one-fifth of the power necessary to take the same load on a good road, and one-fifteenth of the power necessary on a badly kept road. Taking for example, a total weight requiring 15,000 horses on a good road, 3,000 horses will suffice for rail transport, effecting not only an economy of 12,000 horses, but also of 120 tons of forage.

It is, moreover, obvious that the passage of a large number of animals quickly destroys any road; and in 1877, when Bosnia was occupied by the Austrian army, the road from Brod to Sarajevo soon became impassable, in spite of every effort made to keep it in good repair. A tramway, such as can be laid on one side of a road, forming a narrow track for the passage of the horses, leaves the remainder of the road free for troops, and offers advantages not to be despised.

General System Adopted.—To satisfy in full all the conditions of a field railway, it is not sufficient merely that the line can be laid on the surface of the ground without preparatory works; but, further, that this laying can be done as rapidly as possible, and that the line shall be ready for use as soon as constructed. This is met by preparing "bays" or "sections" of line, complete and of various lengths, which can be joined up without difficulty, and, by their flexibility, allow the line to be adjusted to the inequalities of the terrain. These "bays" are light enough to be easily carried by one man, or two men at most. On this principle various systems of narrow-gauge line have been proposed, all of which cannot be here described in full; but an account is here given of the leading systems, viz.:—

(1). The Haarmann type, adopted in Germany.

(2). The Dolberg type, adopted by Austria and Russia.

Haarmann Type.—The Haarmann rail (*Fig.* 1) is of Vignole type, with the following peculiarities:—The web of the rail is not quite

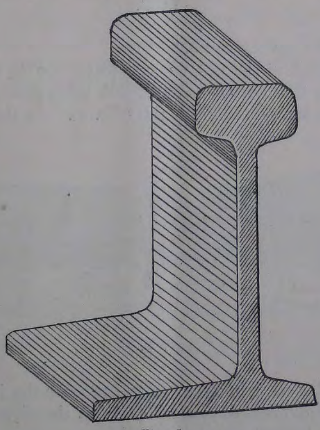

Fig. 1.

at right angles to the bottom flange, and the latter is larger on the outer side of the rail than on the inner. These precautions increase the stability of the rail, and prevent its turning over.

The Haarmann railway is of 60-c.m. gauge, made of bays of various lengths, either of 2 or 5 mètres. The 2-m. bay weighs 35 kilogrammes, the 5-m. bay 80 kilogrammes. They can be carried by 1 and 2 men respectively.

The sleepers are shaped like the letter U (*Fig.* 2), flattened and inverted. Three are laid to each 2-m. bay, 6 to a 5-m. bay. The rail is fastened down to the sleeper by two clip plates secured by screws passing through the sleeper from the underside.

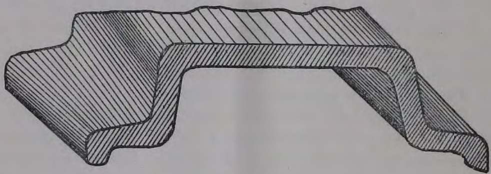

Fig. 2.

The rail joints are of two kinds :—

(*a*). At one end of the rail two fish-plates are fastened; a hook or key, turning through an angle of 90°, being fixed to the end of the plates projecting beyond the rail (*Fig.* 3). At the other end of

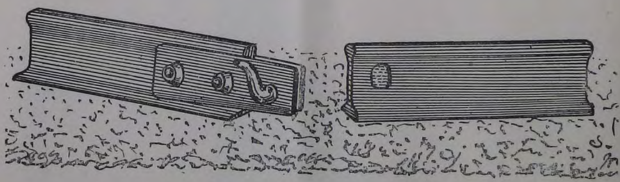

Fig. 3.

the rails an elliptical hole is bored; and to make the joint, this end of the rail is placed between the fish-plates of the adjoining rail, and the key turned through an angle of 90°.

(*b*). In the second type (*Fig.* 4) the key is replaced by a fixed bolt, which fits into a slot cut obliquely in the web of the adjacent rail.

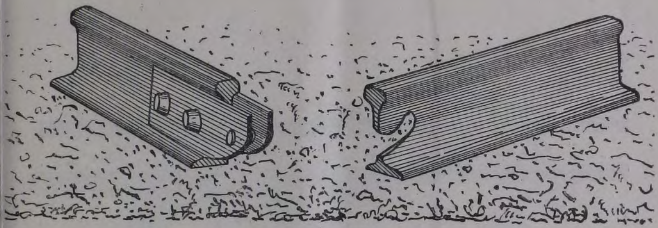

Fig. 4.

Curved bays are provided, 2 mètres in length, the radius of the curve being such that four bays will effect a change of direction at right angles to the original line. The mean radius of this curve is 5 mètres.

Points are dispensed with in this system, and junctions are effected by means of curved bays, the rails being bevelled towards the ends, and laid over the rail of the main line at the point of junction (*Fig.* 5). "Through roads" are made in the same way,

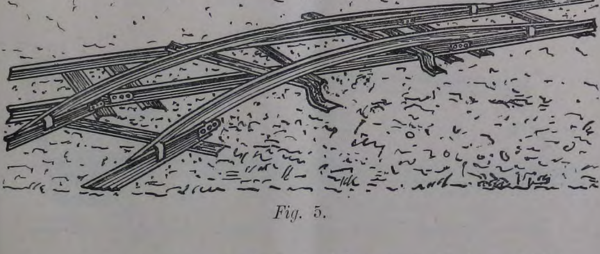

Fig. 5.

the main line being practically bridged by a moveable bay, which is connected with the main line on each side in the same manner as for points (*Fig.* 6).

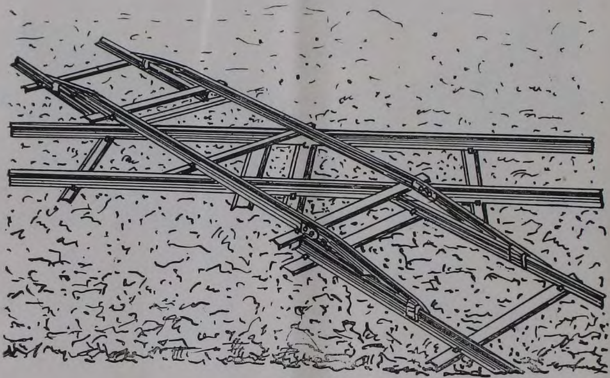

Fig. 6.

Turn tables, mounted on a frame, are provided, and used for through roads, etc., where required.

Ballast is not used by the Germans in laying the line, it being considered sufficient to level the surface of the ground, and fill in the deeper depressions with faggots and fascines. To obviate slipping, the sleepers are picketed down here and there.

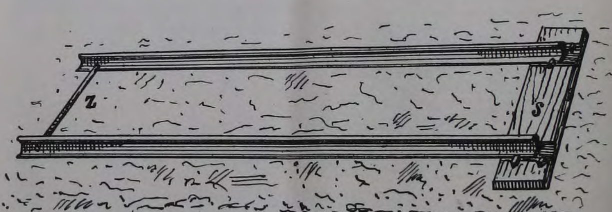

Fig. 7.

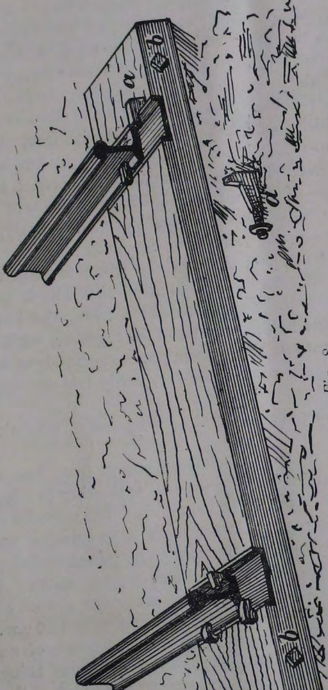

Fig. 8.

Fig. 9.

Rolling stock is, as a rule, very similar to that used in Austria, described above. For laying and working the line, the Austrian and German systems differ in a few small points.

Dolberg System (*Austria*).—The Dolberg system is of 70-c.m. gauge, with bays of 1½ mètres, a single sleeper at one end of each bay, with an iron stretcher rod at the other end (*Fig.* 7) Rail, of Vignole type, weighs 7 kilogrammes per mètre, sleepers 1½ mètres long weigh 28 to 30 kilogrammes. For junction purposes, bays of 75-c.m., 1-m. and 2-m. are provided. The rails are spiked down to the sleepers, which are of wood, in which two slots are cut, lined with iron. The end of the rail passes into the slot, and is there held by two clips passing through the sleeper. The width of the sleeper is such that it projects beyond the ends of the rails, and enables the joints of the rails to be made on the same sleeper, and not perpendicularly, as usual. The clips jointing the rails are shown on *Fig.* 8. It should be added that bolts pass through the wood to keep the sleepers from slipping. The method of jointing the rails is very simple, consisting only of a projecting lug and a hook, the latter engaging under the lug and holding the two rails together, without any fear of accidental separation. This system possesses the advantage of much flexibility, enabling the line to be very easily laid on rough ground (*Fig.* 9).

Curved bays 2 mètres long are provided for purposes of deviation on either side.

When the construction of the line is commenced from two or more points at once, the parties working towards each other to effect a junction, the two ends must finally be closed up. The material of the Dolberg type not being symmetrical, such a junction is not possible, resulting in the ends of two portions to be joined up being of the same description (*i.e.*, both, or neither, sleeper ends). A special junction piece is, therefore, provided to make the closure at these places. When the interval to be closed does not exceed 50-c.m. no sleepers are necessary, and the closure is made by means of an iron framing fitting between the rails, the sides of the frame being rimmed in such a way as to practically prolong the top flange of the rails and bridge the gap (*Fig.* 10).

Everything is foreseen and calculated to assure the utmost speed in laying the line.

Junctions and deviations of all kinds are carried out either by ordinary self-acting points, or as in the Haarmann system.

Rolling stock (described more fully above) is practically the same

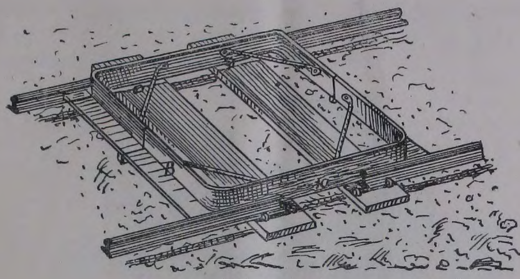

Fig. 10.

in Austria and Germany. The main element is the four-wheeled bogie, which can carry a framework and be used singly, but is more commonly used to make up a two-bogie wagon, with an upper carriage of box or passenger type. *Figs.* 11, 12, 13, 14, 15, 16, show—

Capacity—

Single bogie wagon	3 tons.
Double ,, ,, ...	8 ,,

For continuous traffic 10 double bogie wagons per kilomètre are required, *i.e.*, 5 loaded and 5 returning empty.

(*a*). Single bogie with top carriage.
(*b*). Double bogie provision wagon.
(*c*). ,, ,, passenger car, canvas roof and sides.
(*d*). ,, ,, hospital car, to hold 4 men in 2 tiers. Slung in hammocks. Same as passenger car.
(*e*). ,, ,, devil cart, and method of carrying ordinary horse vehicles or lorries.

Supply of Material.—For each kilomètre of line complete, the following special stores are required in addition to the normal bays, viz. :—

4 closer bays. 2 junction bays.
1 closer frame. 2 sets of points.
20 curved bays.

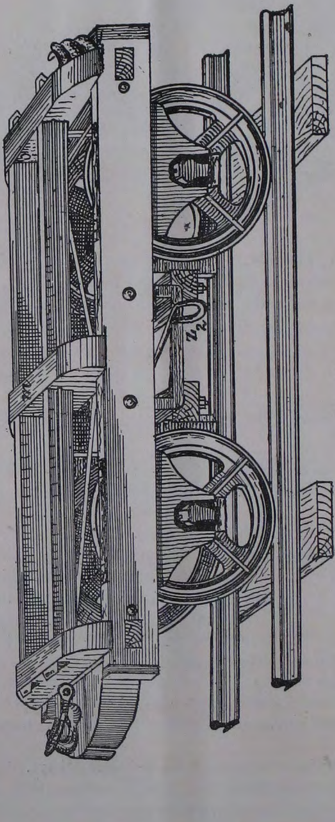

Fig. 11.

This material is conveyed by the ordinary military railway rolling stock, on either single or double bogies. German and Austrian experiments show the capacity to be as follows :—

Single bogie wagons ... ... 20 to 25 bays.
Double " " ... ... 60 to 80 " (120 to 160 mètres).

Two horses can drag three to five wagons thus loaded.

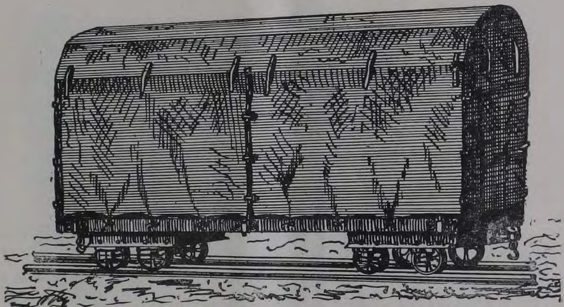

Fig. 12.

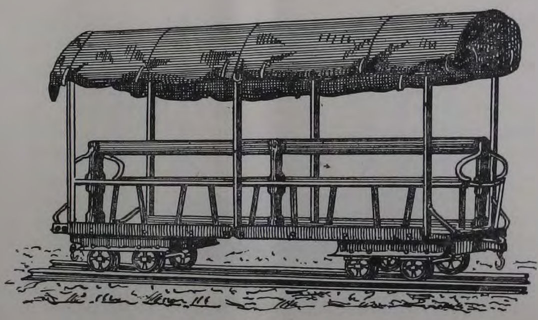

Fig. 13.

Laying the Line.—The system of laying the line is the more important point upon which to decide in considering the question of military railways; and for this, speed is the first essential. Preliminary work and calculations as to trace, embankment and cutting do not complicate the question, being that of simply following the army step by step, the rails being laid on the ground passed over by the troops, almost without preparation. The best means of attaining this result in war is the adoption of a system, and to practice it well in peace.

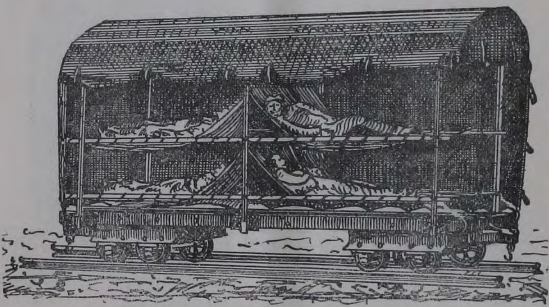

Fig. 14.

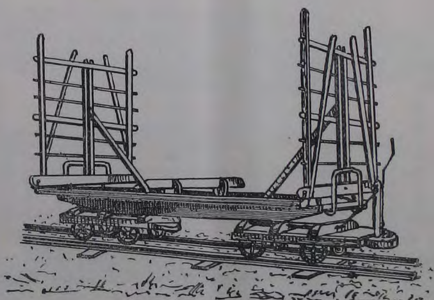

Fig. 15.

Major Tilschkert says that the problem to be faced on service is that of laying the line rapidly, and following the troops; and that all means should be directed to this end. The loading and unloading of the wagons, and the laying of the permanent way, requires a well trained body of men, who will have to be relieved every half-hour if possible, and certainly every hour. The work must be carried out with dash, which can only be acquired by long practice; and the construction of a field railway cannot be undertaken with inexperienced men.

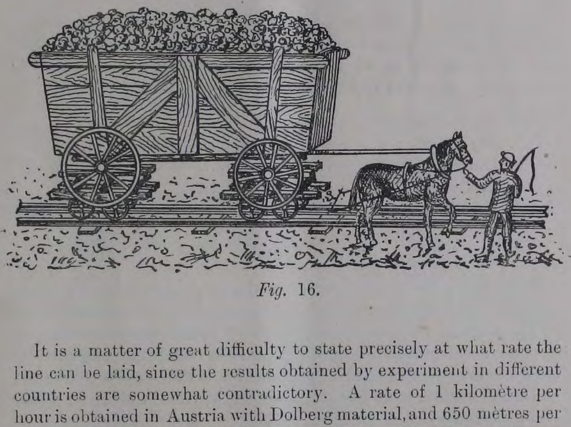

Fig. 16.

It is a matter of great difficulty to state precisely at what rate the line can be laid, since the results obtained by experiment in different countries are somewhat contradictory. A rate of 1 kilomètre per hour is obtained in Austria with Dolberg material, and 650 mètres per hour in Germany (with Dolberg material ?). The German figures may be taken as the most trustworthy, having been obtained under circumstances more nearly approaching those of active service. It would appear reasonable to admit a minimum speed of 600 mètres per hour, giving 14 or 15 kilomètres per day of 24 hours.

Laying the Line (*Haarmann System*).—The following is in brief the system adopted in Germany. For construction work, low and light trollies are used, similar to those employed on ordinary railways. On these the bays are piled, a trolly carrying 15 bays (*i.e.*, 30 mètres of line complete), weighing about 500 kilogrammes. One horse can drag two trollies. As soon as the trolly is empty, it is lifted clear of the line by four men, leaving the rail head clear. The work proceeds till all the trollies have been unloaded, when they are replaced on the rails, and return to the depôt for fresh material.

The working party for laying down the line is distributed as follows :—

1. Formation gang. The preparation can be but very slight.
2. Gang for laying in the line.
3. ,, ,, unloading trollies.
4. ,, ,, pushing and lifting trollies off and on to the line.
5. ,, ,, levelling and packing up the line when laid.

The strength of each gang varies with the nature of the ground, and the weight of bays, trollies, etc. With single bogie trollies and bays weighing 30 to 40 kilogrammes (carried by one man) the total party consists of 16 men, as follows :—

1. Formation gang	4 men.
2. Laying gang	2 ,,
3. Unloading gang	2 ,,
4. Trolly gang	4 ,,
5. Levelling gang	4 ,,
Total	16 men.

When using double bogie wagons, the unloading and trolly gangs must be doubled, giving a total of 22 men ; 3 N.C.O.'s are added.

The work is very heavy, and frequent reliefs are necessary. It does not seem possible to do with less than four parties, each working six hours out of the 24. This, however, is the absolute minimum, and if the work is to be further expedited, a greater number of reliefs will be necessary.

Following the data given above, it is interesting to note the number of wagons or trollies required to lay 14 to 15 kilomètres of line. The system followed from the first is that of loading up the whole of the material at once, necessitating 500 trollies (single bogie wagons) carrying 30 mètres of line each, and 250 horses, for this length of line (one day's work).

System proposed by Major Tilschkert.—Major Tilschkert proposes another method of laying the line, for which he claims a greater rate of progress. He would make use of a number of wagons or carts carried on a platform on two bogies, from which the wagon can be dismounted at will. The platform and bogies are light enough to be carried by men. Each wagon holds 60 to 80 Dolberg bays, 1½ mètres long, 30 kilogrammes in weight, giving a total of 100 mètres of line, weighing 2,000 kilogrammes. Thus 10 such wagons carry all the material necessary for 1 kilomètre of line.

On the wagons the bays are packed in three piles, laid parallel to the direction of the line. Three men unload the material, handing the bays to three men placed on each side of the wagon, giving nine men per wagon, and four to push it. It takes 12 men to lift the wagons and bogies clear of the line when empty.

Tilschkert would use men to push the wagons in the case of the first 10 only (1 kilomètre)—using horses for the remainder of the work. At four men per wagon this requires a total party of—

Pushing wagons ...	10 gangs of	4 =	40 men.	
Dismounting empty ...	3 ,, ,,	12 =	36 ,,	
Laying the line ...	2 ,, ,,	9 =	180 ,,	(two reliefs for each wagon).
Total (exclusive of N.C.O.'s)		=	256 men.	

The actual laying would be done as follows. Each of the nine men forming the laying gang takes one bay; these are hooked on to one another to form a continuous length of nine bays, carried to a point in prolongation of the line already laid, laid down and jointed up. The two gangs succeed each other at the least possible interval. It would appear that the Dolberg system of jointing facilitates laying on this system. There are certain serious disadvantages in the method, of which the most important is the heavy work thrown on to the horses, which must travel backwards and forwards along the line. It seems, from the time taken, that some trains are expected to cover as much as 50 kilomètres in the 24 hours. This would be excessive if the work was to continue for any length of time, in which case the number of teams must be doubled. There is also the additional disadvantage of a large traffic, amounting to 34 trains a day in each direction on a 15-kilomètre section, for constructional purposes only, over and above the trains required for ordinary traffic working.

The system would appear only practicable for lines of inconsiderable length, or in special circumstances. When wagons can be spared, therefore, the first system described above seems best, all the material necessary for the 15 kilomètres being loaded up at once; and the wagons, when unloaded, becoming available for ordinary traffic purposes over the line, which will be clear almost to the rail head.

As a further disadvantage of the Tilschkert system, it may be added that 150 wagons and 300 horses are required per 15 kilomètres, with about a dozen extra for siding construction.

Traffic Arrangements.—When Laying the Line.—If the number of wagons is insufficient to enable the whole of the material to be loaded up at once, construction can be commenced by distributing this beforehand at various points, from which it can be carried forward as required by a few wagons working backwards and forwards between depôts and rail heads. Sidings for crossing purposes are necessary when working in this manner, to enable full and empty wagons to cross when moving in opposite directions.

To regulate the traffic under such circumstances, a table must be worked out, based on the rate of progress at rail head, accommodating the speed of trains to this, arranging that the rail head work shall not be interrupted, and that wagons shall not stand idle longer than absolutely necessary.

A time table has been got out on the supposition that the work progresses at 600 mètres per hour with Haarmann material, the trains moving at 4 kilomètres per hour. This table shows that continuity of work can be assured at the rail head with 45 double bogie wagons, each drawn by two horses and carrying 100 mètres of line. The three first trains to consist of seven wagons; remainder of six wagons. Trains to follow one another at intervals of one hour. Sidings 60 mètres in length are necessary every 3 kilomètres.

Capacity of Line when Completed.—Having given a short account of the system of laying the permanent way, we proceed to examine the carrying capacity of a line of this nature worked by horses. This depends, briefly, on the number of horses available, and the speed of the trains.

We agree with Major Tilschkert that 10 double bogie wagons per kilomètre are sufficient for good working. On a line 200 kilomètres in length, this would give 1,000 wagons moving in each direction. Wagons moving to the front could not carry more than *three* tons, though as much as 10 tons can be drawn by a horse on level ground. When loading wagons for the continuous journey, the load is ruled by the worst part of the line; and if this be taken as a gradient of 1 in 20, a load of three tons with two horses will be found sufficient.

No difficulty should be experienced in maintaining a speed of 4 kilomètres per hour, and on level ground this can be raised to 5.

or even 6 or 7. At a speed of 4 kilomètres it will take 50 horses to cover 200 kilomètres. Allowing for work between 6 a.m. and 10 p.m. only, and that each horse will cover 15 kilomètres with a full load, and the same distance with an empty wagon, the train service works out as follows:—

15 kilomètres	$= 3\frac{3}{4}$ hours
Changing horses	$= \frac{1}{4}$ hour
Total	4 hours,

giving a distance travelled of 60 kilomètres in the 16 hours. Thus a little over three days are required for the journey of 200 kilomètres. On the 60 kilomètres (one day's journey) there will be 600 wagons in movement, 300 in each direction; and 300 wagons, carrying 900 tons of stores, will arrive at the front daily. These 300 wagons will be despatched in six or eight trains of 50 to 60 wagons at intervals of two hours. For crossing purposes, a siding 200 to 300 mètres in length is provided every 3 to 4 kilomètres, the siding holding a train of 60 wagons.

It may here be mentioned that sidings cause much inconvenience when the line runs along the side of a main road, and should not, therefore, be too numerous, it being more advantageous to concentrate them into a smaller number of long sideways at greater intervals. The trains, for this reason, should consist of a larger number of wagons. As an example, three or four trains, made up of 75 to 100 wagons each, at intervals of four hours, will require a siding at intervals of $7\frac{1}{2}$ kilomètres.

The question as to how far the concentration of the daily service into a few long trains can be carried is one that wants much looking into, and is not as yet properly threshed out.

It is evident that telephonic communication should exist along the tramway, and that the stations, placed 15 kilomètres apart, should be so arranged as to allow of changing teams with the least possible delay. The details of station arrangements are outside the scope of these pages.

Comparison.—Broad Gauge *v.* Narrow Gauge.

The figures given above, which will, of course, vary with the conditions of the problem, show clearly the value and importance of a narrow-gauge horse tramway.

A railway of the normal gauge, working ten trains a day in each direction, would have a carrying capacity equal to five single lines on the narrow-gauge system. The total load transplanted would in both cases be 4,500 tons; but the broad-gauge line would possess the inconvenience of undue concentration at the front, the stores having to be carried from the rail head to the various portions of the army at varying distances. The five separate heads of the narrow-gauge military lines, of equal total carrying capacity, would both simplify and expedite the work of distribution.

APPENDIX.

Manual *v.* Horse Traction.

The advantages offered by horse tramways in the field are so great that the principal European armies have provided themselves with railway material, and carried out experiments to determine the system on which this should be laid down and worked. These trials have shown that even horse traction is not always possible, and that when, for example, the ground is soft, or the road on which the line must be laid is too narrow, recourse must be made to other modes of transport. It must be noticed that the teams cannot walk between the rails, and require a path about 1 mètre wide beside the line, which path must be kept in good condition. On a good metalled road the line can be laid as near the side as possible, the horses making use of a narrow strip near to the rails, leaving the greater part of the road free for troops. In such a case the use of a railway or tramway is simple, and carries every advantage. In less favourable circumstances roads may be non-existent, and the line must follow country paths or be carried across country, and it may happen that from lack of material a metallized track cannot be laid for the horses. Lastly, horses themselves may be scarce and impossible to obtain, and the question arises as to whether or not, in such cases, the many advantages of transport on rails are to be entirely renounced. The Austrians say no, and when it is considered that their army would be called upon in war to operate in countries where roads are few and far between, and railways conspicuous by their absence, surprise cannot be felt at their solution of the problem, strange though it may appear at first sight.

The Austrian scheme is simply that of replacing horses by men, and a few words may be said on the possibilities of the system considered, as it is in Austria, in connection with the special circumstances in which it would be used.

Major Tilschkert thinks that it may raise a smile to talk of transporting the supplies of an army by means of man traction on rails, but in a flat country, on badly maintained roads, this system is far more practical than that of the ordinary horse and cart. Country roads, and even metalled highways, very quickly deteriorate in the course of a campaign, and soon become a sea of mud and impossible to use. It is then that the advantage is seen of a tramway worked by men, whose power of traction is thereby increased by four or five times, and rendered less liable to delay and mishap.

For the purpose of comparing the loads drawn by one man or one horse on different natures of roads, Major Tilschkert, to whom we are indebted for all information given on this subject, makes use of the following formula :—

$$Q = \frac{F - Ptgi}{f + tgi},$$

in which

Q = weight drawn.
F = tractive force.
P = weight of horse or man respectively.
f = coefficient of resistance due to nature of ground.
tgi = gradient.

The force P = 13 kilogrammes for a man weighing 65 kilogrammes walking on level ground at speed of 80 centimètres per second.
P = 60 kilogrammes for a horse weighing 300 kilogrammes under same conditions.

From this formula the following tables have been drawn up :—

Gradient.	Weight Drawn (in kilogrammes).					
	Country Road.		Metalled Road.		Tramway.	
	Man.	Horse.	Man.	Horse.	Man.	Horse.
Level ...	130	600	533	2,000	2,166	10,000
1 in 100	112	518	307	1,425	792	3,265
2 in 100	98	450	234	1,080	450	2,077
5 in 100	65	300	122	562	174	802
10 in 100	32	150	50	230	61	283
15 in 100	13	60	18	83	21	96

It will be noticed that the load drawn by both man and horse decreases rapidly with the steepness of gradient, but it must be added that when the incline is of no great length, say not exceeding 500 or 600 mètres, it is possible to exert a power double that shown in the table. On a tramway, for example, on an incline of 15 in 100 (1 in $6\frac{2}{3}$), and 600 mètres long, a man could draw 42 kilogrammes, and a horse 192. It will further be noticed that the advantage of the tramway decreases as the gradient increases ; and with the same gradient as above, 1 in $6\frac{2}{3}$, the tramway shows very little superiority over a good metalled road.

The most important point to notice, and that to which we particularly wish to call attention, is that man traction on a tramway is more economical than horse traction on a country road when the gradient does not exceed 1 in 20. This is partly due to the consideration that every team of two horses must be accompanied by a driver, who adds nothing to the tractive power, and partly to the fact that each horse requires 10 kilogrammes of grass per diem, while the weight of a man's food is only one kilogramme. Major Tilschkert has calculated that, under such conditions, one man is equivalent to 1·8 horses.

It is assumed in the above remarks that forage and food would require to be brought from the base to each station. Even if found in the neighbourhood, however, the relative superiority of the man, though decreased, is still maintained.

Major Tilschkert then goes on to show that the wear and tear on the road beside the line will be much reduced, and that on the softest soil the track can always be made practicable for men by laying down a plank between the rails.

We shall not go further into this question of the employment of men for tractive purposes on field tramways, but we have simply wished to point out that in this matter the Austrians are extremely practical, and are by no means content to rest on theory. Every year experiments in this direction are being carried out on the training ground at Koeneubourg, which show the intention of the Government to make use of this means of transport, and, if necessary, to requisition the labourers from the country occupied by their troops.

Conclusions.

The following paragraphs, therefore, show the tendency in Germany, Austria and Russia in the nature of railway and tramway transport in the field :—

(1). Locomotives will only be used outside the zone of active operations, viz., on lines of communication, or in the attack and defence of fortresses. In other words, they will and can only be used when it is possible to construct the permanent way with the necessary time and care.

(2). Horse, and eventually man, traction, will be employed within the zone of operations when it is necessary to follow troops on the march.

Austria already possesses 600 kilomètres of narrow-gauge line; and the provision of material in Germany is in progress, the sum of £248,000 having been voted in 1893 for the purchase of railway stores for field service. Of this sum £100,000 is being expended in the present year.

In conclusion, it may be remarked that the employment of field railways for supply purposes will largely diminish the number of horses required for working in rear of the enemy. These horses will thus become available for combatant purposes, the number of which will be considerably increased.