THE NEW RAIL AND CLEARANCE MEASURING DRAISINE OF THE AUSTRIAN FEDERAL RAILWAYS

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1. Introduction

The Austrian Federal Railways have now a new rail and free space measuring vehicle (Fig. 1). It has been constructed by Plasser and Theurer in Linz (as a special version of their EM 80) in cooperation with Norma (a daughter of SIEMENS in Wiener Neudorf) and the Institute of Photogrammetry and Remote Sensing of the Technical University in Vienna /6/. One purpose is to measure the rails' geometry at full speed, how, is reported in short in the next chapter. The second purpose is to measure synchronously tunnel profiles and possible obstacles for over gauge loads by means of an Austrian laser device and by photogrammetry, respectively, and this is reported in detail in the third chapter. The last chapter deals with software for the restitution and for the database system.

Fig. 1: The rail and clearance measuring draisine of the Austrian Federal Railways (1986).

2. Instrumentation to measure the rails' geometry

The tolerances of the track sections have to be checked one to four times a year /7/. Exact knowledge of the rails' geometry is a necessary prerequisite for any economic use of computer controlled tamping machines. Without these, no modern high speed railroads are possible, because only these machines are able to place the metals accurately enough.

The data necessary for the correct judgement of the rails' geometry is measured every 25 cm under similar circumstances as in practical traffic stored and processed in the central computer Perkin Elmer 3205 (25 MHz, 32 bit). The results are plotted on endless paper: Gauge, curvature, top level, cross level, twist, and milage /8/, (Fig. 2). The vehicle has two loaded main axes at 6 m distance. Between and symmetrically outside of them are three units with unloaded telescope measuring axes distanced 2 times 5 m. Measuring wheels pressed against the rails palpate the metals mechanically. Linear inductor-encoders send the distance informations to the computer which processes the data in real time.

Thus **gauge** is measured by means of the two halfs of one of the unloaded telescope axes.

Curvature is computed from the three left and the three right halfs of the telescope axes, i.e. by three points chord measurement for each rail separately. The massive base frame of the vehicle guarantees the proper relation of the measurements.

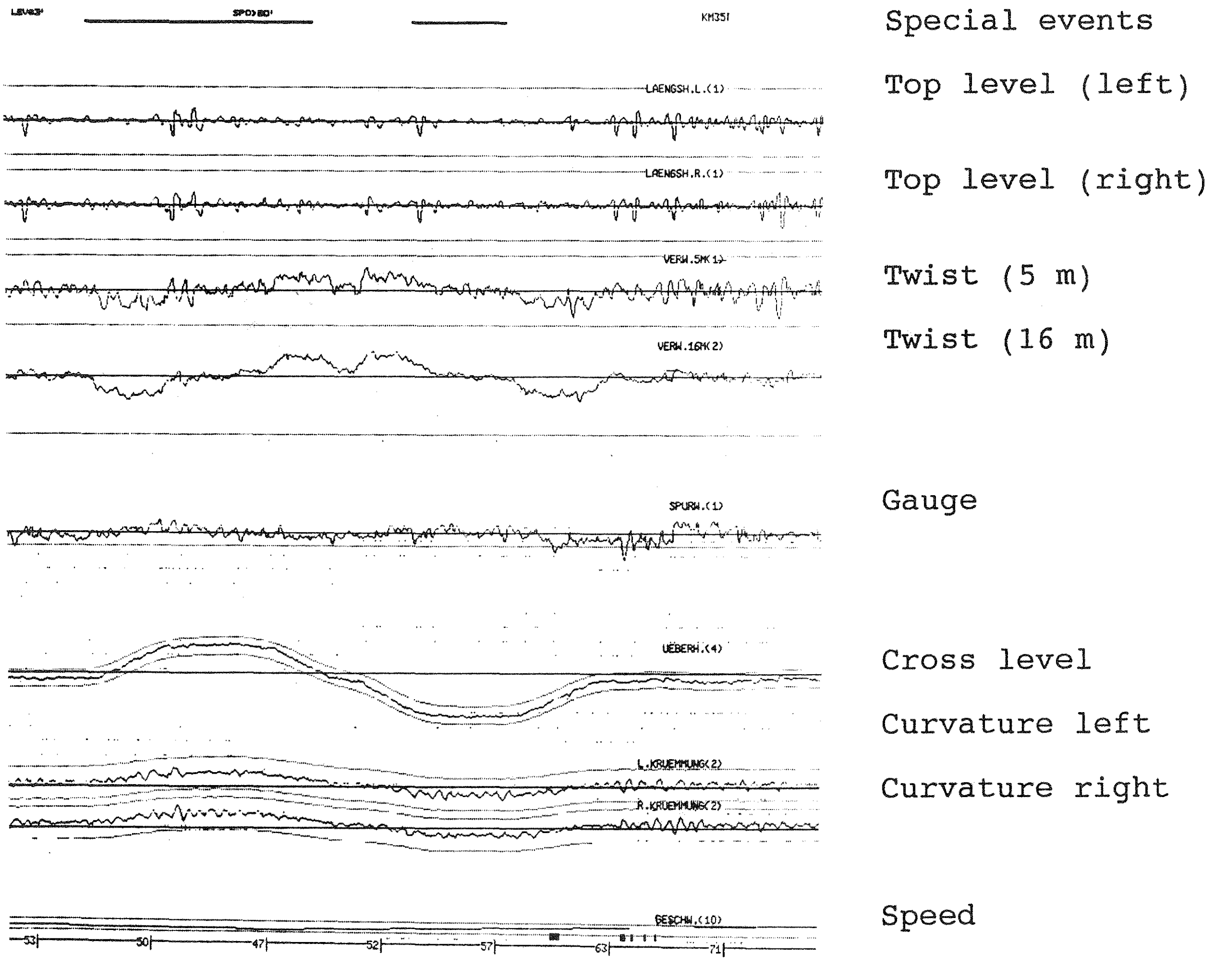

Fig. 2: Printout showing the rails' geometry graphs.

Cross level is determined by means of a centrifugal force compensated gyro system, i.e. by an artificial horizon related to one of the loaded main axes. The inclinations measured are automatically compensated for the spring paths of the axes' ends.
Twist is measured by the difference of the cross level at a given base (5 m).
To determine **top level** means practically vertical three points chord measurement, where the outer points are the ends of the unloaded axes and the inner point is the end of a loaded axis, and this for each of the two rails.

Besides that, **special events** may be recorded. Some buttons are at the drivers disposal, e.g. for bridge, tunnel, switch, etc. Another special event is the release of the shutters of the photogrammetric stereo camera.

Fig. 3: The impulse laser system RIEGL DM 900 in cross profile working position

3. Instrumentation for mensuration of clearance

3.1 Free space mensuration in tunnels

The walls of tunnels do not reflect enough flash-light for photogrammetry. It seems more appropriate therefore to use a special impulse laser system DM 900 of the Austrian firm Dr. J. Riegl, Horn. On the third measuring axis of the draisine a supporting beam has been fixed in longitudinal direction which holds the laser device in reference to the tangent plane.

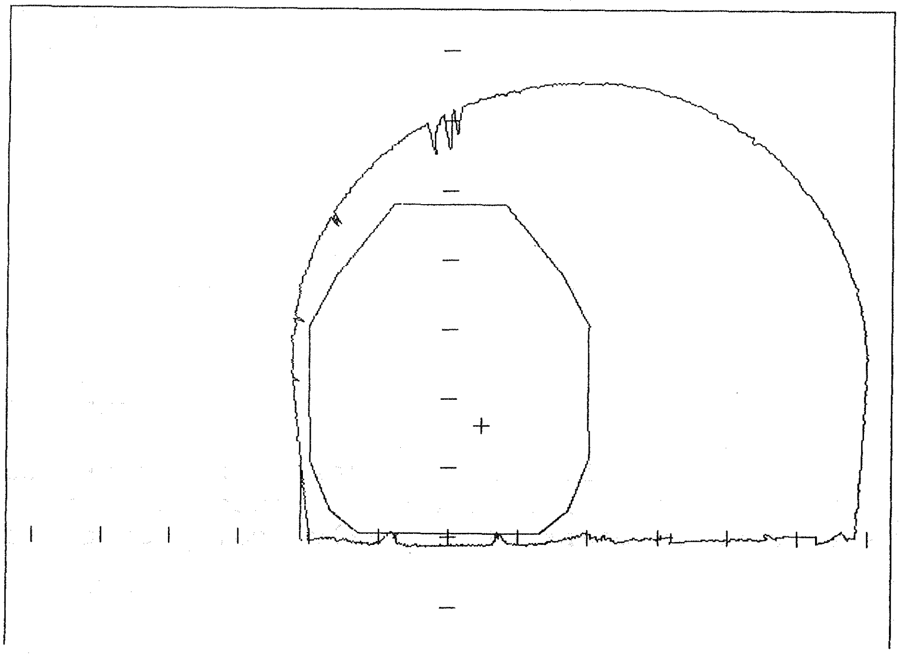

Fig. 4: Cross section of a tunnel (originally 1:100)

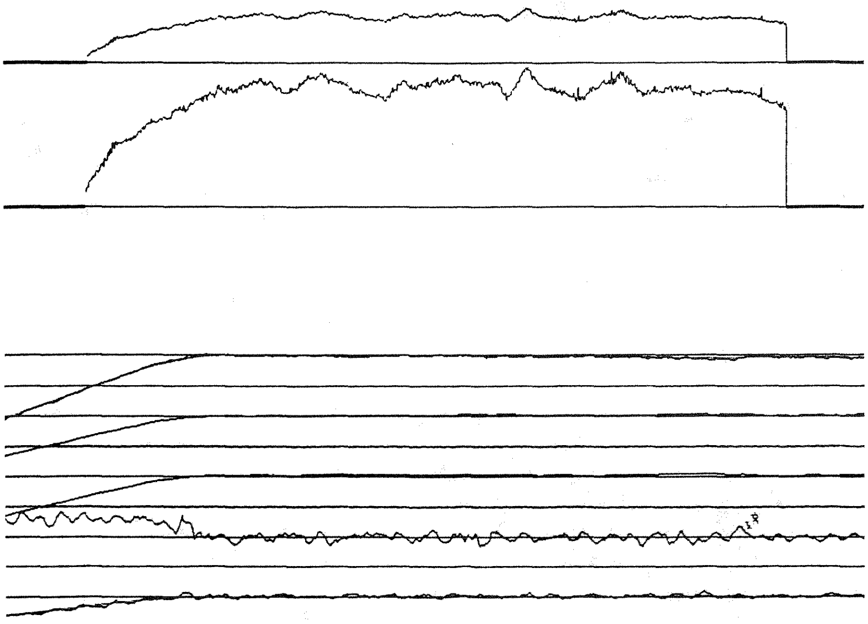

Fig. 5: Printout showing a longitudinal section of a tunnel (originally 1:50) and some parameters of the rails' geometry.

A computer controlled stepper motor rotates the laser beam. 1000 steps are possible for 400 gon. The laser device measures the distances to the wall of the tunnel and plots the profile in one of the scales 1:50, 1:100 or 1:200. One profile takes one to three minutes. The accuracy is approximately 1 to 2 cm (Fig. 4).

For longitudinal profiles of tunnels the measuring direction of the laser will be fixed. The draisine and the laser beam scans then the tunnel wall driving at a speed of approximately 15 km/h. Every 25 cm all the rail and profile data is recorded (Fig. 5). For tunnel profiling the respective track section has still to be closed for any other traffic.

3.2 Free space mensuration outside of tunnels

For any track a certain standard free space is available. But the industry asks also for transportation of extra large cargoes, as e.g. power plant boilers, oil reservoirs, big steel girders for bridges, other finished structural parts, etc.

Along the 6000 km of Austrian tracks there are about 60.000 to 80.000 possible obstacles. One third of it are supposed being in the Vienna area: Signals, walls, roofs, masts, trees, platform edges, etc. From now on these obstacles are being photographed by means of a special photogrammetric stereo-camera, restituted by means of an analytical plotter, and the

Fig. 6: Special transport of a chemical reactor for the oil industry (Photo Austrian Federal Railways)

results are stored within a new database system for all the Austrian tracks. Later on, also other "obstacles" shall be added, as e.g. local maximum load tolerances, speed limits, etc.

It is not a new idea to use photogrammetry for this purpose. In Sweden and Danmark it is long used routine (/1/ to /5/). But there a control profile trailer is used, which is positioned along with the obstacle and stereo-photographed together with the obstacle while the train stops. The control profile defines automatically the correct cross section coordinate system in relation to the position and cross tangent of the rails. The tracks are blocked for a rather long time, too long for the havy traffic in Austria. Therefore a procedure has been sought which allows for photogrammetric recording at full speed, at least at 30 km/h, the mean speed of a local train. The measuring draisine then may follow any local and does not block up the track section.

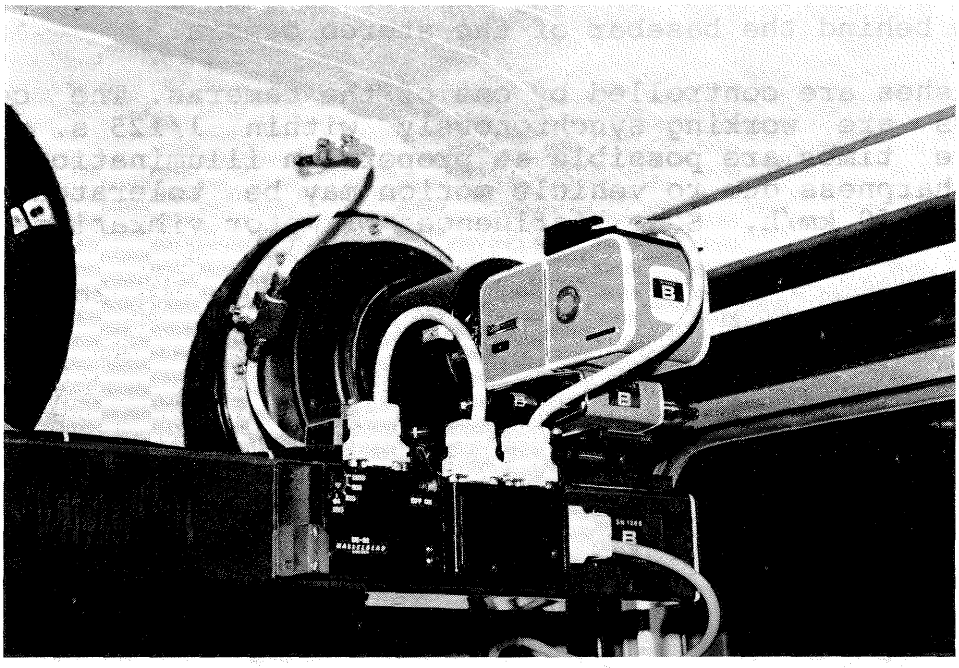

Fig. 7: Hasselblad MK 70 on the base beam
in working position

The new solution is using a fixed base stereo camera with a base length of 1940 mm and two Hasselblad MK 70 with ZEISS Planar f = 100 mm in 6 gon convergent position; the point of convergence is at 20 m taking distance (Fig. 7). This allows for maximum use of the camera format 53x53 mm and 100% overlap for the fixed taking distance of 20 m. The optics are protected against the outside by optical flats which are cleaned from moisture, if any, by an air stream. The camera window covers may be closed by compressed air thus protecting the optical flats against rain and insects in case of backwards drive of the draisine. The distortion of the objectives amounts to 0.03 mm in the corners of the images and may be compensated for by means of an analytical plotter during the restitution process. The reseau plate of the MK 70 has 25 crosses. On one side of the image a computer controlled information line may be exposed onto the film. This capability allows for recording of such information as track name, track section, track direction, date and time, profile number, name of the obstacle etc. This is important because of the similarity of the images.

There is no automatic exposure meter installed, because these are working mainly for the center of the image whereas the objects here are somewhere around the center, only. The practical tests showed that manual setting of time and aperture is sufficient if a powerful flash is added for the illumination of the shadows. Therefore a double reflector flash is installed inbetween the two cameras (Prophoto PRO-3, Stockholm). Its light is powerful enough (2400 Ws) to show the reseau crosses of the image center also in night photographs. Its guide number (stop number times distance in m) is 201 for 21 DIN films and 50°-flash-reflectors. The shutters are released semi-automatically. Passing an obstacle the operator presses a button. From now on the computer takes over control and releases the synchronized backwards showing cameras as soon as the obstacle is 20 m behind the basebar of the stereo camera.

The flashes are controlled by one of the cameras. The computer shutters are working synchronously within 1/125 s. Shorter exposure times are possible at proper sun illumination, only. The unsharpness due to vehicle motion may be tolerated up to a speed of 60 km/h. Some influences of motor vibrations and of

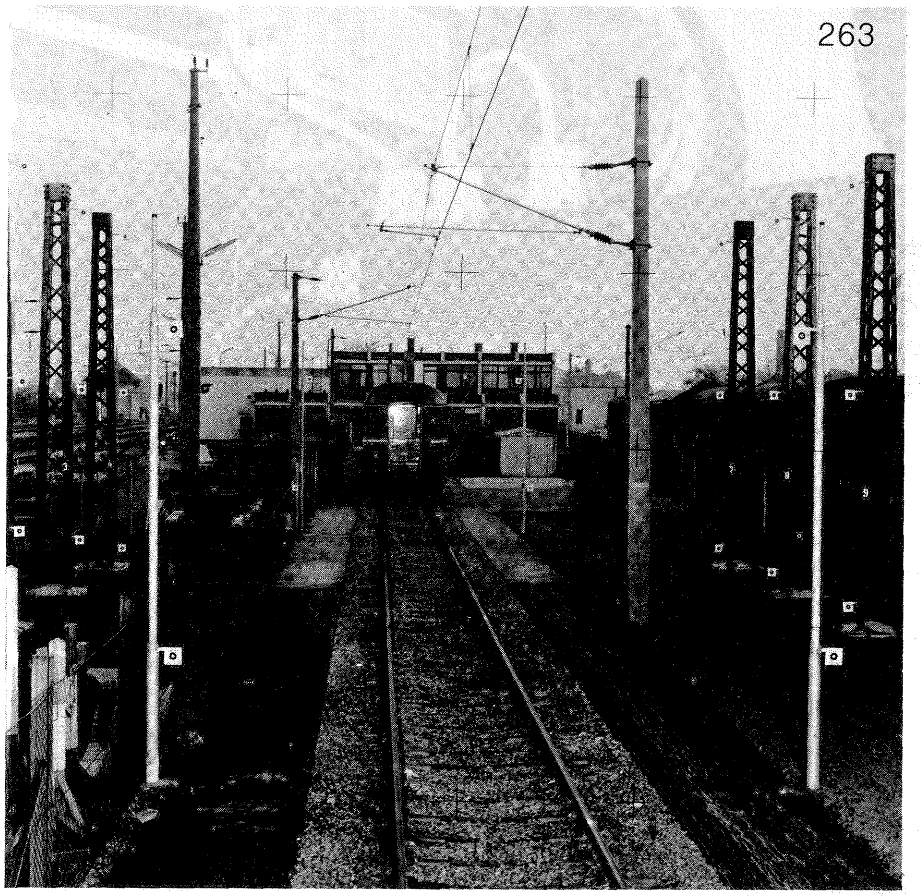

Fig. 8: The test field for the control of the orientation parameters

rail joint shocks remain visible in spite of a good shock absorber system. Up to now all the photographs could well be used for restitution, which is done at a Wild BC2 analytical plotter controlled by a DG 30 (512 KB) computer with a magnatic tape unit.

4. Software

The software for the system consists of two parts. The first part is a measuring program for the restitution of the stereo pairs, the other part is a database program for the management of the profiles measured by means of photogrammetry or by means of the laser device.

4.1 Software for the restitution

Relative and absolute orientation of the stereomodels are problematic because the upper half of the pictures usually shows heaven, the center corresponds to infinite, and there are no control points available. The cameras are mounted on a robust and constant base bar, therefore the relative orientation can be assumed to be constant. For the determination and for the periodically repeated control of the relative orientation a test field has been established in the home station of the draisine. On 10 grid masts 26 signals have been fixed and geodetically measured with an accuracy of ±1 mm (Fig. 8). The outer orientation derived from that test field by means of the first model of a period will be used also for the models taken along the track, at least at first. Thus relative orientation is achieved accurately. The absolute orientation is correct to scale but not with respect to rotations. Also the origin of the profile co-ordinate system is still unknown. It is aimed to measure within a co-ordinate system, whose origin is in the middle of the rails' inner edges and in 20 m distance

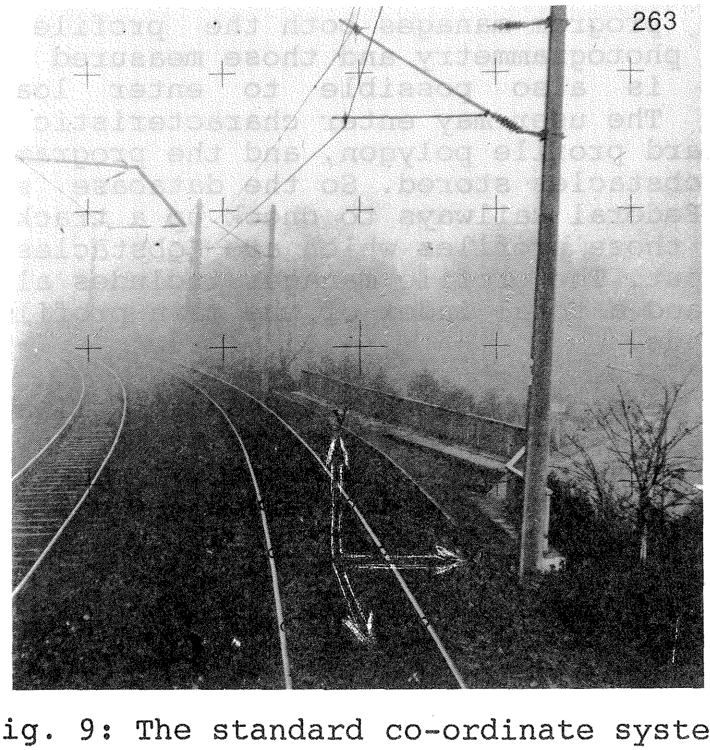

Fig. 9: The standard co-ordinate system for cross profiles

off the base bar. The x-axis should be tangential across the two rails. The (xy)-plane is supposed to be orthogonal to the rails' plane (Fig. 9). Therefore on each of the two rails 3 points are measured in distances of 16, 20 and 24 m, respectively. The analytical plotter shows automatically their approximate position, the operator measures the edge of the rail at these distances accurately. These 6 points define now an adjusting plane, into which the 6 points are projected. These 3 pairs of points define the local axis of the rails, computed as an adjusting straight, which defines the z-axis. The vector perpendicular to the plane determines the direction of the y-axis, and the vector product the x-axis. The components of these three unit vectors give us the elements of the rotation matrix, by which the rotation matrices of the two images have to be multiplied in order to rotate the co-ordinate system into the proper directions. The position vectors of the two projection centers and of the (20 m)-axis-point are then being transformed into the new system. Afterwards the system is shifted so that the (20 m)-axis-point forms the center of the wanted co-ordinate system.

Now the analytical plotter offers to automatically check a standard free space polygon with variable speed. The operator sees whether the inside of that polygon contains some parts of the obstacle or not. If not, the operator may switch over to the next model. If yes, it arises the question, whether the obstacle is within the zero-plane, behind or in front of it. The zero plane may be shifted after the measurement of one typical point. Obstacles are then measured by means of a polygon which will be stored on a disk file together with some attribute data (track number, rail number, track km, other geometrical data from the draisine's tape).

4.2 Database software

The database program manages both the profile types, those measured by photogrammetry and those measured by the laser system. It is also possible to enter load or speed restrictions. The user may enter characteristic over gauge or another standard profile polygon, and the program will compare it with the obstacles stored. So the database system enables the Austrian Federal Railways to check up a track for a certain profile. Only those profiles which are "obstacles" are then the program's output. The profile manager includes also INPUT, SHOW and DELETE, and a total index of the main profiles of typical over-gauge loads.

The measuring team of the Austrian Federal Railways trained in September 1987 has now a mass of work to be done. If 6 models are measured per hour, i.e. 10 minutes per model!, it takes 10 man years to measure the Austrian profiles just the first time.

Summary:

The Austrian Federal Railways in cooperation with Plasser and Theurer, Linz, have developed a new rail measuring draisine by which the rails' geometry as well as the clearance around the rails may be measured. The parameters of the rails' geometry are: gauge, curvature and top level, cross level, twist, and distance gone.

For measurement of clearance two systems are installed. The first system is assigned to profiling in tunnels and consists mainly of an impulse laser measuring system DM 900 of the firm Dr. J. Riegl, Horn, Lower Austria. The longitudinal as well as the cross profiling is described in detail. The second free space measuring system is a photogrammetrical one and serves for the survey of possible obstacles outside of tunnels. Its theoretical development has been done by the Institute of Photogrammetry and Remote Sensing of the Technical University Vienna, the practical development was in the hands of the firm Norma (Optics, Electronics and Measuring Techniques Ltd., Wiener Neudorf). The photogrammetric system consists of a 2 m fixed base stereo camera with two Hasselblad MK 70 in 6 degrees convergency position. The system allows for taking pictures backwards while travelling up to 60 km/h. No control profile trailer is needed as by previous free space measuring systems. Restitution is done by means of an analytical plotter Wild BC2. The software enables the operator to economically collect the digital data.

The obstacles will be managed by a proper data bank system which may be asked in the future in any case of transports of extra large cargoes. The erection of this data bank is of great importance for a modern management of over gauge loads.

References:

/1/ Magnussen M., Björklund P., Torlegard K.: Technische Untersuchung von Transportwegen für Sendungen mit Lademaßüberschreitung bei den Schwedischen Staatsbahnen. Archiv für Eisenbahntechnik, Darmstadt 1975, issue 30, p. 41-54.

/2/ Torlegard K.: Free Space Determination for Large Railway Cargoes by Stereophotogrammetry. VIAK, Vällingby, 1976, 4 pages.

/3/ VIAK AB Consulting Engineers: Which Track for Extra Large Cargoes? Prospectus, VIAK, Vällingby 1976.

/4/ Aaberg O.: Photo Trolley. Danish State Railways. Copenhagen, 1978, 14 pages.

/5/ Danish State Railways: Administration of Special Consignments (Out of Gauge Loads) with Computer. Copenhagen 1983. 23 pages.

/6/ Plasser und Theurer: EM 80. Prospectus R3/D 683.

/7/ Presle G.: Der Oberbaumeßwagen der Österreichischen Bundesbahnen. Eisenbahntechnik, 1983/4, p. 24-28.

/8/ Presle G., Waldhäusl P., Mann H.: Das neue Gleis- und Lichtraum-Meßfahrzeug der Österreichischen Bundesbahnen. Österreichische Zeitschrift für Vermessungswesen und Photogrammetrie, 75/4, p. 208-218, 1987.

Zusammenfassung:

Die Österreichischen Bundesbahnen haben mit der Linzer Firma Plasser und Theurer einen neuen Gleismeßwagen entwickelt, mit dessen Hilfe einerseits die Gleisgeometrie erfaßt werden kann, andererseits aber auch Lichtraummessungen möglich sind. Zur Gleisgeometrie gehören Spurweite, Pfeilhöhen (horizontal und vertikal), Überhöhung, Verwindung sowie die Kilometrierung.

Für die Lichtraummessung sind zwei Systeme installiert. Das erste System dient zur Profilmessung in Tunnels und besteht im wesentlichen aus einem Impulslaser-Meßsystem DM 900 von der Firma Dr. J. Riegl, Horn. Die Längs- und Querprofilmessung werden im Detail beschrieben. Das zweite Lichtraummeßsystem basiert auf Photogrammetrie und ist für die Aufnahme von Hindernissen außerhalb der Tunnels vorgesehen. Seine Entwicklung wurde vom Institut für Photogrammetrie und Fernerkundung der TU Wien betreut. Die Organisation und Ausführung lag in den Händen der Firma Norma, Optik, Elektronik und Meßtechnik GmbH, Wiener Neudorf. Das photogrammetrische Aufnahmesystem besteht aus einer Festbasis-Stereomeßkamera mit 2 Hasselblad MK 70 in leichter Konvergenzstellung. Das System gestattet Aufnahmen nach rückwärts in freier Fahrt mit bis zu 60 km/h. Es ist kein Paßpunktwagen wie bei früheren Meßsystemen mitzuführen. Die Auswertung erfolgt an einem analytischen Auswertegerät Wild BC2. Das Auswerteprogramm ermöglicht eine wirtschaftliche Datenerfassung.

Die Hindernisse werden in einer Hindernisdatenbank verwaltet, die in Zukunft für Transporte mit Lademaßüberschreitungen abgefragt werden kann. Die Aufstellung dieser Datenbank ist im Hinblick auf ein modernisiertes Sondertransportwesen von großer Bedeutung.