Forensics and Physics

Forensics and Physics

By

Renata Holubova, Jiří Straus
and Jana Slezáková

Cambridge
Scholars
Publishing

Forensics and Physics

By Renata Holubova, Jiří Straus and Jana Slezáková

This book first published 2022

Cambridge Scholars Publishing

Lady Stephenson Library, Newcastle upon Tyne, NE6 2PA, UK

British Library Cataloguing in Publication Data
A catalogue record for this book is available from the British Library

ISBN (10): 1-5275-8407-0
ISBN (13): 978-1-5275-8407-5

TABLE OF CONTENTS

List of Illustrations

LIST OF TABLES

INTRODUCTION

Dear readers!

The presented publication entitled Forensics and Physics deals with criminological aspects of investigations from the point of view of science, especially physics. The book you hold in your hands deals with solving complex scientific research tasks when examining forensic traces and during forensic identification. The publication is based on extensive suggestions from literary, professional studies, and articles in professional journals. An interesting and key element is the connection between forensic - criminology and physics. Physics can be seen as a scientific field whose content is the study of the most general properties, states, and changes of material objects. Physics comes with its knowledge in three basic ways. The first method is the observation, e.g., observing the fall of a shot person. The following important method is an experiment by which we observe the phenomenon in artificially prepared conditions, such as the fall of a training dummy by shooting. The third method is to create hypotheses based on observations and experiments or based on the knowledge of the phenomenon. Thus, we create a scientifically substantiated idea of the course and causes of the occurrence under investigation.

The book is divided into four main chapters. Forensic trasology deals with the method of finding and securing trasological traces. The general principles of securing trasological traces are given here. The biomechanical content of trasological traces is mentioned and the connection between walking and physics is discussed. It is worth mentioning the explanation of mechanical work during ordinary walking and the list of average values of mechanical force during various movements that a person performs.

The second chapter deals with the biomechanics of falls. The introductory part explains that the fall of the human body is a compound movement, which consists of movement in the horizontal direction and free fall. The text explains in detail the classification of falls using a training dummy, whose weight parameters, dimensions, and location of the center of gravity are the same as for a living person.

Dactyloscopy is the content of the third chapter. This is the oldest method of identification in criminology. Dactyloscopy is a scientific field of forensic technology that allows you to identify a specific person under optimal conditions. It shows how dactyloscopic traces are found, made visible and secured, as well as how they are examined based on the evaluation of dactyloscopic features. Attention is paid to applications in the field of optics and molecular physics

The last chapter deals with the issue of forensic ballistics, which, due to the nature of the use of weapons, is mostly dedicated to the study of small arms. It is explained in detail that it is not just the science of firearms of all types and kinds. Forensic ballistics is, among other things, a scientific discipline that also examines by-products of firing, objects with traces of impact, etc. Emphasis is placed on the question of the mechanism of criminological traces during the shot itself and after leaving the projectile from the weapon. Of interest is the description, classification, and identification of firearms. In the part concerning physical applications, the reader will encounter, for example, the concepts of energy, kinetic energy, variable force, work, work in the gravitational field, mechanical energy saving, projectile energy, Coriolis force, Magnus effect, and projectile motion. Their meaning and use in connection with the issue of forensic ballistics are always explained.

The appendix Differential and Vector Calculus is focused on physical applications in mathematics. This section mentions the historical development of differential and vector calculus. The text contains an overview of basic definitions and theorems about the derivation of a function of one variable. The terms are supplemented by explanatory figures. The subchapter Vector calculus deals with the introduction of the term-oriented line and its size, the definition of bounded and free geometric vectors. The introduction of vector coordinates in plane and space is also shown here, as it is directly applicable in applications in physics and engineering. The reader is acquainted with selected solved problems on physical topics in connection with criminology.

We believe that the presented publication will be of benefit to all who are interested in the currently most used examination techniques and their significance from the point of view of physics.

Dear readers, we wish you a lot of joy and lots of new knowledge while studying this publication.

—Authors

CHAPTER ONE

FORENSIC TRASOLOGY

Introduction

Trasology is a field of forensic technology that deals with the search for securing and examination of footprints, footwear, means of transport, and traces of other similar objects. Trasology examines the traces of these objects if features of the external structure of the objects (morphological features) are highlighted in the trace. It is a science of traces, which examines a trace as a representation of the outer side of an object to identify those objects or to determine group affiliation and to clarify all the circumstances associated with the emergence of a trasological trace. The objects of research are trasological traces, which can be divided into the following groups:

a) footprints of bare and worn feet,
b) traces of human locomotion
c) traces of means of transport
d) other traces of similar species.

Traces of bare and worn feet are created by contact of the bare foot or the bottom of the shoe with the pad. They are therefore the result of the reflection of the outer structure of the flat feet or sole, heel etc. These traces may have general (typical) so as special (specific) characters. Footprints of shoes are created by contact of the bottom of the shoe with the pad. The bottom of the shoe can be:

a) Sole – can be monolithic, bloc or rolled (cut out), injection molded, pinned and quilted. Covers the lower part of the shoe upper (top) from toe to heel.
b) Heel – it is either a part of the sole (monolithic) or forms a separate part of the bottom of the shoe. It is made of various materials. From the criminological and technical point of view, the most important is the so-called bollard (the upper part of the heel). Separately pressed

Figure 1-1. Types of soles (monolithic, block sole without heel, doweled with attached sole and heel, part of the rubber plate from which the rolled sole is cut, rolled sole)
(Straus, Porada et al, 2004, p. 26-27).

bollards give us the opportunity to distinguish new from old-repaired – shoes, although if both cases bollards with different patterns are often used.

c) Tread – covers the lower part of the shoe from the toe to the niche, while the sole from the toe to the heel. It is cut by machine or by hand from various materials and can be smooth or variously shaped. The tread is attached to the upper by sewing, doweling, nailing and gluing. The treads are mainly used for repairing worn shoes.

Footwear footprints essentially provide the possibility of identification, which, however, depends on the quality of the footprint. In the case of smooth soles, the entire imprint is usually required, in the case of shaped soles, sometimes only the marginal part is sufficient to determine whether it is:

a) Men´s, women´s, or children´s footwear;
b) Footwear of a certain type, shape, size, etc. (group features);
c) Certain footwear (individual features).

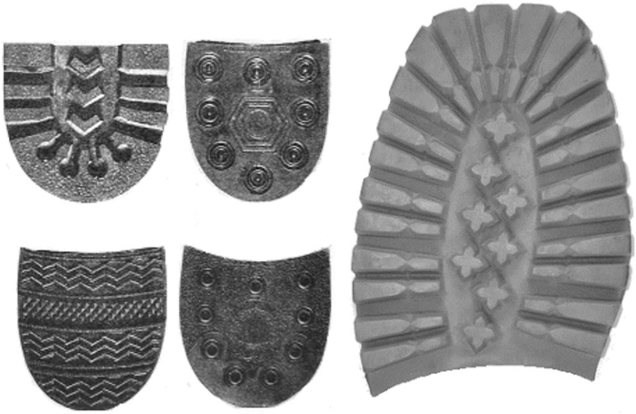

Figure 1-2. Heels and sole
(Straus, Porada et al, 2004, p. 26-27).

Group affiliation can be determined by comparison in the sole collection and in the footwear production catalogs. Individual identification can be carried out only if the footprint contains some peculiarities caused by production, use, and wear or repair (scratches, punch, trampling), which cannot appear in the same arrangement in the second shoe.

The surface trasological footprint of the bare foot is called as the bare foot **plantogram** (sometimes called podogram, especially in the medical orthopedic literature). The plantogram is created by the contact of the foot with the mat due to the natural loading of both legs by the body weight during the dynamics of walking. Plantograms are relatively rare in crime scenes, but they can occur, so it is necessary to know their geometric characteristics. Traces of bare feet are examined in trasology only if they do not show usable features of papillary lines (otherwise they are examined in dactyloscopy).

Vehicle tracks – this group of tracks includes tire tracks, tracks of rubber, wooden, and metal wheels, tracks of tracked vehicles, and track of skid vehicles.

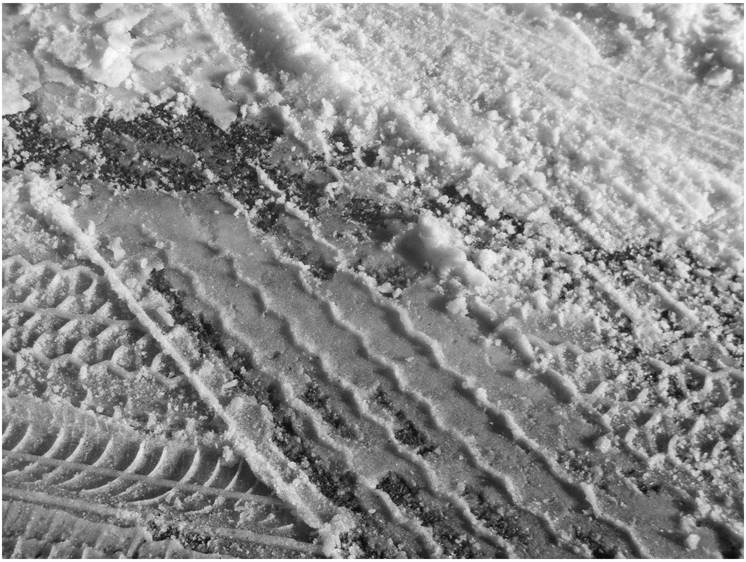

Figure 1-3. Traces of vehicles
(https://pixabay.com/cs/photos/stopy-pneumatik-sn%C3%ADh-silnice-497461/)

Traces of vehicles are created by direct contact of wheels, belts, or sliding surfaces of skis and sleds on a pad (road or open terrain). Under certain conditions, significant information about the technical characteristics of the vehicle, structural elements of the external structure (shape, dimensions) of the object that created the tracks can be obtained (the reflection of the structure of the treads of tires, rims, belts, skis, and sleds).

There are general and specific features in traces of this type. General features are important in terms of determining the group affiliation of the object (relatively stable and unchanging shapes and dimensions of some parts of the tire pattern, track and wheelbase of the vehicle, etc.). These features are common to a particular type of tire or vehicle. They are therefore material sources for determining such parameters as the shapes and dimensions of patterns and size of tires, type of vehicle, type of the car, etc.

Specific features relating to a particular object are material sources for determining the identity of the object that created the track. Under certain conditions, the contact surfaces of the tire treads and the rims of the wheels, the belt, but also the skid surfaces of the skis and sleds may reflect features which are specific only to a particular object.

In terms of their origin, the traces of means of transport are divided into groups:

1. Tires for bicycles, motorcycles, cars, tractors, etc.;
2. Rubber or iron wheel rims of agricultural and other machines;
3. Tracked vehicles;
4. Skid vehicles (skis and sleds).

Traces of tires on bicycles, motorcycles, cars, etc. are created on the ground (road, open terrain) by turning the wheels when the vehicle is moving or when it is standing. Depending on the mechanical properties of the surface, either flat or volumetric traces are created. The tire tread pattern reflects its shape and dimensions in the case of volume marks at the bottom of the tread. In some cases, crushed tracks are created that do not display the specific features of the reflected object in the required quality (e.g., when the tire tread slips on the road, when braking, etc.).

Traces of wheel rims of agricultural and other machines occur infrequently. Tracked vehicle tracks are mainly volume tracks (impressions) caused by articulated belts, which usually have a significant shape and depth of impression in the soil due to their considerable weight. Tracks of skid vehicles are created by skidding of the sliding part of skis and sledges on a snowy road or in open terrain. In most cases, there are volume traces.

Other traces of similar type include traces of lips, ears, knees, elbows, fists and palms, gloves, socks, luggage, traces of animal feet, crutches, support sticks, etc. if they reflect the morphological features of the object. They arise under suitable conditions by contact with other objects, e.g., when the offender is resting on a dusty wall, pad or window frame, on the ground, etc. Mostly these are volumetric traces. In some cases, there are also flat marks, such as traces of knees, elbows, gloves, etc.

1.1 Searching for and securing of trasological tracks

Searching for footprints of feet, shoes, means of transport, and other tracks, was carried out by searching for crime scenes in buildings, or, more often, directly in the terrain. Attention must be paid to both isolated tracks, resp. fragments of fit, as well as two sets of tracks, such as a locomotion trail. Depending on the mechanism of traces, surface and volume traces can be found at crime scenes. It is necessary to search for the track systematically from the moment of entering the search area, either in the building or in terrain. The traces found are suitable, marked, and protected against adverse weather conditions or damage, such as trampling. The traces are fixed and secured for expert examination. Trasological traces are provided in the original, by photographing, casting, or removal.

When searching for plastic traces of bare feet and human locomotion, it is not possible to limit oneself to the place of the event. However, it is necessary to search for these traces in a wider area. Areas to which special attention should be paid are:

- The crime scene in the narrower sense - it is the specific area where the crime was committed. For example, when committing violent crimes, there is often a struggle or other activity that results in a large number of trasological clues at a particular crime scene. Traces can be left in the victim´s blood, clothing, and body, such as a wall as on objects kicked on the floor during the match. When breaking in, there may be objects on the floor, such as safe insulation, paper, or other rubbish, on which trasological traces may be kept.
- Place of entry – this is the place where the offender entered the crime scene. Violent entry occurs when the offender enters the object of the unnatural way and usually, he is more likely to step on objects, rubbish, etc. Usually provides a greater opportunity to find clues than if the crime scene where the normal entry occurred, such as the door. Trace locations should also include the outer areas of the site immediately around the point of entry, such as flower beds, verandas, balconies, etc.

- Path of transit – the path that the offender has passed through the scene is depending on the nature of the crime scene, the identification of the point of entry, the place of the offense, and the point of departure. Wherever the passage is obvious, traces of human locomotion and bare and worn legs should be carefully sought (dusty and dirty surfaces - cellar, back porch).
- Route of departure – may be difficult to identify. Often traces can be found around trees, bushes, where the perpetrator hid. Areas covered with snow, soft soil, or sand can provide an extensive amount of traces of human locomotion and bare and worn feet.

Immediately after finding the track, its technical and tactical value is preliminarily evaluated. Only tracks or sets of tracks that show significant and appropriate general and specific identifiers shall be provided.

The principles of providing trasological tracks are general and special. The general principles define those aspects that must always be observed, regardless of the type of trasological track. The principles that are important only for a certain type of trasological track are special. Failure to comply with even one of the principles below will run the risk of reducing the quality of the secured track, which will lead to the impossibility of the group and thus rather individual identification. Equally important, the track would lose its tactical and criminal law significance.

General principles of providing trasological tracks:

a) Completeness - we provide all known tracks at the crime scene, as only a forensic expert has the power to decide whether the track is usable or not.
b) Integrity - we always provide the entire track, never just a part of it.
c) Speed - as tracks are affected by internal and external influences that affect their quality and usability, they must be secured as quickly as possible, considering the precision of securing.
d) Track protection - closely related to the principle of speed. The track must be suitably protected from damage until it is secured and handed over for examination.
e) Accuracy of documentation of the place of detention - is especially important for the elaboration of an expert opinion, but also for other activities of bodies active in criminal proceedings (forensic experiments, verification of the testimony on the spot, repeated and additional search of the crime scene, etc.).

f) Priority of nondestructive securing methods - if it is possible to apply nondestructive securing (in nature photography), it always takes precedence over destructive (casting, removal of a dactyloscopic foil, electrostatic scanning etc.).
g) Priority of search and seizure - first, tracks should be found and secured at the entrance to the crime scene and on the floor (ground).

The special principles of securing trasological tracks are:

a) If possible, we always ensure the track in nature.
b) We always, without distinction, provide tracks by scaling using appropriate photographic highlighting methods. Because the film may be damaged, we take the picture twice.
c) Pour the plastic tracks or, on the surface track, remove them with a dactyloscopic foil.

Examination of bare feet and footwear footprints - a trasological track created by a person may contain not only information important for the possibility of determining group affiliation. It may also enable individual identification of a man or footwear according to footprints of the bare foot, resp. worn legs, but may further include substantiated information about the offender's movement behavior and some of its somatic properties. The projection of them on the track is not excluded due to the various mechanical connections between the track-forming object and the track-receiving object.

When examining and evaluating bare feet, it is necessary to consider some negative factors that affect the outcome of the examination. These are in particular:

a) relativity of the dimensions of the bare foot;
b) differences in area and volume track values;
c) the mechanism of track formation (free walking, running, jumping, etc.).

Examining the track of bare feet usually allows only the determination of group affiliation, especially in cases where the track reflects and examines only the shape and size of the foot and its parts. From this point of view, grouping and different finger shaping are of considerable importance. All elements of the foot and its parts which have been reflected in the track must be measured with each other accurately. The acquired foot shapes and dimensions are group identification marks. In summary, they can make it possible to create a closer characteristic of the person who created the researched track.

Examining footwear tracks involves determining group affiliation in the first stage, in some cases it is not always an easy task. In some cases, it is difficult to distinguish between men's and women's footwear, as they often match size and patterns. Sometimes the difference between the bottom of men's shoes and women's shoes is significant, e.g. in width, heels, finer patterning, etc.

Figure 1-4. 3D trasological trace (Straus, Porada et al, 2004, p. 38)

In the process of determining the group affiliation of footwear, knowledge of basic production technology, and footwear records (catalogs), photographs of sole patterns are used. Often no track is required to identify a group of shoes. The size of the footwear can also be determined according to the track of the patterned block and especially the monolithic heel. According to the tracks of the designs of these types of shoe soles, it is possible to determine relatively accurately, the size, but usually also the type, shape of the shoe sole and upper. According to the track created by the smooth sole, the determination of group affiliation is only possible approximately. For heel tracks, the so-called sowing (i.e., distance and location of circular holes for nails) can be used, which is proportional to the size of the heel.

The size of the secured track cannot be compared with the shoe size number without appropriate corrections. It depends on the mechanism of the track and the properties of the footwear as well as the properties of the material in which the track is formed. It also depends on the type of footwear that created the track. In most cases, the track is slightly larger (depending on the size of the shoe framing). The differences can be 1, 2, or more centimeters, which corresponds to one to four size numbers.

The technical value and quality of the group identification marks exhibited by the size and shape of the sole and heel and their designs, as well as the method of attachment, are decisive for determining the group membership of the footwear.

Individual identification of footwear is based on the existence of specific features reflected in the track of the micro relief of the surface structure of the sole, a sole or heel. The specific character of these features lies, in essence, in the individually unique, completely random, and incomparable unevenness of the bottom surface of each individual shoe.

The forensic technical examination of footwear is an examination of the macrostructure of the surface of the bottom of the footwear. This is due to the fact that the material of the base (various types of soil, mud, linoleum, asphalt, etc.) does not have such properties that it can accept or reflect the microstructure of the relief of the shoe sole.

Unevenness in the external construction of the shoe sole surface is caused by the manufacture, use, and repair of the shoe. Production-specific features can only occur in footwear with a rubber rolled bottom. Specific features given for use are created by trampling, sitting, penetration of various objects into the bottom of the shoe, etc. Specific features given by the repair are created when attaching the sole, bollard, repairing the sole, sole, heel, etc.

The track of a shoe, i.e., each individual track, contains certain information about the shoe that created that track. It therefore contains features that can, in a favorable case, lead to individual identification of the footwear. However, already in the first phase of the examination (until a piece or pair of shoes to be compared has been secured), it is possible to determine not only the group belonging to the shoes, but also certain information about the person who wore these shoes (under normal circumstances) - height, albeit statistically on average, i.e. regardless of individual disproportionate variations.

When evaluating **the tracks of a locomotion trail** (walking, running, jumping, or a combination), it should consider that the walking of some people is not regular, but has an individual character, which is displayed in the trail. Therefore, whenever a continuous set of walking tracks is provided at the crime scene, due care must be taken.

To evaluate the walking path, it is necessary to carefully measure and draw in particular:

a) length of the track (shoe or foot imprint);
b) width of the track (shoe or foot imprint);
c) step length (this is the longitudinal distance of the heel of the right and left foot in the walking direction);
d) the length of the two-step (it is the longitudinal distance of the heel of the right and right foot in the direction of walking or the left and left foot);
e) track angle (angle between the axes of the foot and the longitudinal direction of walking).

According to research in recent years, the biomechanical content of trasological tracks of locomotion can be decoded in bipedal locomotion tracks. The biomechanical content of trasological tracks created during bipedal locomotion can be understood as the reflection of some biological properties of a person and his movement behavior in the track created during mechanical interaction with the substrate.

Examination of tire tracks and various tracks created by means of transport - examination of tire tracks is performed to determine the group affiliation of wheeled vehicles, most often cars. It is based on the existence of characteristic identifiers which are common to a certain type (group) of tires and a certain type (group) of cars.

The individual identification of wheeled vehicle tires depends on the existence of specific features reflected in the surface or volume footprint of the tire tread surface of a particular vehicle, such as a car.

The bearer of group identification marks is the tread pattern of the tire treads regarding the structural location of individual wheels in connection with the wheelbase and track of the car. The following identification features are decisive for the group determination of the membership of wheeled vehicles with tires: tire dimensions, tread shape and dimension, track, and wheelbase of the vehicle.

The size of the tire indicates the width of the tire tread and its inner diameter. Width and circumference, resp. tire diameters are important group identifiers. They make it possible to determine the production dimensional markings of the tire, which are typical for only a few types of cars. The width of the tire shown in the track can be obtained by measuring the distance from the edge of the pattern of one side to the edge of the pattern of the other side. To determine the circumference of the tire, it is necessary to look in the track on a continuous route for two consecutive marked specific characteristics, such as a certain type of tire damage. The determined tire size is then determined from the measured tire circumference dimension with the help of specialized catalogs.

The size **of the basic tread shape** is always proportional to the size of the tire. There is a so-called ribbing (gap) between the individual figures of the pattern. The dimension of the basic shape of the tread changes. The tread pattern is created according to precise matrices, so all products in the series are identical. The dimensions of the ribbing depend on the tire pressure, the weight of the load, and the condition of the road. Therefore, the dimensions of the ribbing vary according to the specific conditions.

The wheelbase of cars is different. It is determined in feet by measuring the distance from the center of the right wheel track to the center of the left wheel track. In the case of lorries, if they are equipped with twin wheels, the track gauge is determined by measuring from the center of the space between the pair of wheels. Most cars have different front and rear wheelbases. The wheel tracks are best detected in a slight bend, when the tracks of the front and rear wheels do not overlap. The wheelbase of the vehicle does not have a constant value. It depends on the vehicle load, direction and speed of travel, vehicle wear, and whether it is a vehicle with a fixed or split axle. Therefore, when determining the size of the track after measuring specific values, it is necessary to take into account a certain tolerance. The size of the track in connection with the shape of the tread and the dimensions of the tire makes it possible to narrow down the circle of inspected objects to the smallest number.

The most important group identification feature is **the wheelbase of the vehicle**, i.e., the distance between the front and rear axles. This is because almost every type of vehicle has a different wheelbase size. The possibility of detecting the wheelbase is only given when turning backwards or during heavy braking, when the locking tracks of the front and rear wheels of the car are created.

In the case of reversing rotation, the wheelbase is determined by measuring the distance from the leading edges of the marked front and rear wheel tracks. The measured values can be different between the right and left wheels. The measurement is always subject to a certain error.

In the latter case, for the measurement, which is analogous to the previous example, the completed locking tracks of the front and rear wheels are authoritative.

When evaluating the wheelbase, deviations can be taken into account, which can be caused by material wear, various chassis repairs or suspension properties, and the degree of tire inflation. All listed features of group affiliation make it possible to determine the type and type of cars in summary.

The individual identification of wheeled tires is based on the quantity and quality of irregularities in the surface structure of the tire tread, which could not have arisen in terms of spatio-temporal arrangement of two or more objects of a similar type used in different conditions. These characters shown in the track are therefore naturally considered random and non-repeatable characters. The origin of their origin and their uniqueness individually, but especially in their summary, are unique to the individual surface of a single, specific tire tread.

Specific identification features arise by:

a) detrition when the tire is used;
b) various repairs.

The features caused by tire detrition are different. They can be cuts, markets, cracks, or grooves. Furthermore, various smaller objects, such as nails, stones, fragments of glass, metal, etc., can be pressed into the tire.

The features caused by the repair of the tire tread are local and given by the individual repair during the use of the tire. They occurred, for example, as a result of a puncture or other damage to the tire.

Examination of the tracks of other motor vehicles with tires does not allow as detailed a group delimitation of objects as is generally possible in determining the group affiliation of an automobile. For these vehicles, there are not so many group identification features (structural-technical elements) that, according to their reflection in the tracks, would allow to narrow the range of inspected objects to a certain group (motorcycles, tractors, etc.). Depending on the size of the tires, the shape, and the size of the tread, it is not possible to determine exactly the type or type of vehicle.

For some means of transport, e.g., single-track, the possibility of group identification features, such as gauge (not applicable) and wheelbase, cannot be used. In the case of agricultural vehicles, one type of tire is commonly used on the wheels of different types of machinery, which makes it difficult or even impossible to determine the group membership of a particular means of transport.

Under certain conditions, the examination of tracks created by means of transport is of tactical importance. It is mainly a comprehensive and consistent evaluation of the track, respectively on-site tracks, as they can help to determine the direction of travel, the approximate speed of the vehicle, and, where appropriate, the type of vehicle.

The determination of the group affiliation of tracked vehicles depends on the group identification features, such as: the length and width of the belt and the dimensions of the belt links. According to these features, the given type of tracked vehicle can be determined.

The length and width of the belt are determined similarly to tires. The length of the belt is determined by measuring the distance between the repetitive features displayed in the belt track. The width of the belt is given by the distance from the outer edge to the inner edge of the same belt. The dimensions of the belt link are determined by longitudinal and transverse measurements.

Individual identification of the tracked vehicle is possible on the basis of specific features reflected in the track. These characters are of different shapes. They are caused by wear, deformation of the belt, or by replacing individual belt links.

The determination of the group affiliation of wheeled vehicles with rubber or metal rims is possible on the basis of group identification features such as: the width of the rim tracks, the dimension of the outer circumference of the rim and the track gauge of the vehicle. These characters can be used to further characterize the vehicle with metal rims. Due to the nature of these vehicles, it is not possible to determine their form, shape, or purpose according to the displayed tracks.

Individual identification of vehicles with rubber or metal rims can usually be done very rarely, as the reflected traces in most cases show very few usable specific features (e.g., the shape of the rim, weld, significant wear or deformation of the rim, etc.).

The determination of the group affiliation of the sledge can usually be performed only according to the displayed profiles and the width of the sledges, their gauge and the sliding surface shown in the track. As with determining the group membership of skis according to the reflected tracks in the snow, there is only a limited possibility of using these tracks to determine the group of these objects, respectively, for their closer characterization.

Individual identification of sledges and skis is practically limited to the existence of only such peculiarities exhibited by sliding surfaces of sledges and skis, such as objects in sledge fittings, places of random deformations of sliding surfaces of sledges and skis, etc. These peculiarities can be detected under certain conditions; quality, shape, and size, so that they can be considered as specific features specific to only one specific object (sledges, skis), which were reflected in the trail. In some cases, the tracks of ski poles may also reflect specific features (e.g., features of various repairs or modifications) that can be used for the forensic identification process.

Examination of tracks of objects of a similar type can lead to the determination of individual identification, often there are tracks of the outer ear lobe on the door, or tracks of gloves, teeth, and lips. These tracks are examined by scoring, overlaying, or a combined view.

1.2 Biomechanical content of trasological traces

Trasological traces of bipedal locomotion are a typical representative of traces that reflect the functional and dynamic properties of the acting object (person). From these traces it is possible to decode the biomechanical content. The biomechanical content of trasological traces is classified into geometric, kinematic and dynamic features.

Geometric features of the biomechanical content of trasological tracks are manifested mainly in the spatial arrangement of the track (track set) in the length, the width and area of the track, in the depth (volume) of the plastic track, and in the spatial relationships between tracks in the track set. The basic characteristics of the geometric features of the biomechanical content of trasological tracks include: length and width of footwear, length and width of bare foot, length of right and left foot steps, length of right and left step, left and right foot angle.

Among recent works that have broadened the so far sparse basis for the analysis of the biomechanical content of tracks, enhancing the possibilities of criminalistic identification by these means, the most notable is that by Titlbach et al. The authors of this study have treated the question of the existence of relationship, and their numerical expression, between the dimensions of the soles of the feet and body height, between the dimensions of soles and shoes, and between the sizes of shoes and body height. The statistical analysis of this problem involved the following parameters: body height, mass of the body, length of the sole of the foot, width of the sole, shoe length, shoe width, shoe type, age. The individual geometric somatic parameters were measured either by common anthropometric methods or by means of a special device for the measurement of the dimensions of the soles of feet. These experimental data provided the basis for an evaluation of the statistical characteristics of the random variables involved. i.e., their mean values, standard deviations, and the average error in the mean. Furthermore, the length/width ratio of the sole, the difference between the length of the sole and that of the shoe, and the difference between the width of the sole and that of the shoe were computed. Statistical treatment of the final set of data yielded information that seemed to indicate the following correlations:

1. Body height depends on both the length and the width of the sole.
2. With increasing body height, the length of the sole also increases within a certain scatter band with the average rate of this increase being 2.5 cm/cm (increment of height against that of the length of the sole).
3. A simultaneous correlation exists between body height and the width of the sole, the ratio between the increments in body height and the width of the sole being 4.5 cm/cm.

The correlations defined above allowed an empirical relationship to be constituted for the prediction of the probable body height of an average individual depending on data on the dimensions of the soles of his feet in the form of

$$vT = 3.1\, d\mathrm{n} + 4.0\, s\mathrm{n} + 53 \text{ (cm)},$$

where vT represents the body height (cm), dn is the sole lengths (cm), and sn is the width of the sole (cm).

The probabilistic relationship between body height and shoe size was determined in an analogous manner. This correlation can be expressed as

$vT = 2.6\ do + 4.3\ so + 55$ (cm),

where do is the shoe size (cm) and so stands for the width of the shoe (cm).

These relationships allow the probable body height of an individual to be evaluated on the basis of numerical data on the dimensions of his feet or on the shoe size. The scatter band of these two correlations' lies within the $\pm$ 1 cm limits to the mean curve, which represents acceptable accuracy for practical purposes.

In subjectively normal walking, the average stride length of 70 cm was experimentally determined and the length of the two-step in the same type of walking is 142 cm. Analytical dependencies vary around these statistical averages as follows:

a) step length (d_K) – body height (v_T)
   - up to 70 cm step length, the relationship applies
   $vT = 0.297\ dK + 153$
   - over the 70 cm stride length, the relationship applies
   $vT = 0.315\ dK + 163$
b) length of two steps (dDK) – body height (vT)
   - up to 142 cm, the two steps length, the relationship applies
   $vT = 0.157\ d + 151$
   - over 142 cm, the two steps length, the relationship applies
   $vT = 0.175\ dDK + 155$

If at the crime scene a set of at least four consecutive tracks is found, there are several ways to determine the height of the person who created the tracks. It is possible to use the dimensions of the footprint, or it is appropriate to use the relationships given above. If we want to obtain the body height as accurately as possible, it is suitable to use more independent methods. The accuracy of the calculation and prediction of body height can be set to ± 2 cm. The highest accuracy is achieved using the maximum number of input parameters.

Several functional dependencies exist for these needs. According to experimental verification, the following two ways of determining body height from walking parameters appear to be optimal:

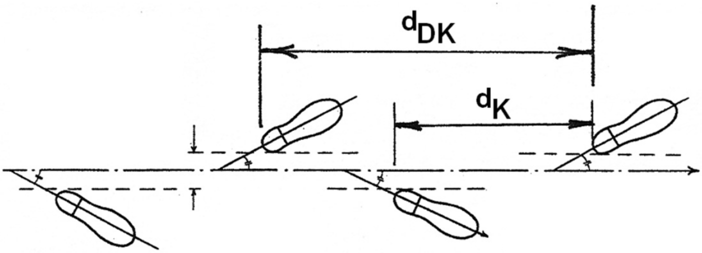

Figure 1-5: Stride length and two-step locomotion

1. determination of body height from stride length (*d*K) and two-step (*d*DK)

$vT = 0.153\ dK + 0.083\ dDK + 155.5$ (cm)

2. determination of body height from stride length, two-step length, footprint length (*d*DO) and footprint width (*d*SO)

$vT = 0.076\ dK + 0.041\ dDK + 1.35\ dDO + 2.4\ dSO + 101.25$ (cm)

The mentioned functional dependences apply to subjectively natural walking on a flat surface without external influence. From the known equations, we can present a suitable number of different equations for all variants of input variables for the needs of criminalistic practice with a suitable mathematical combination. The body height of the offender can be calculated according to the measured parameters of the locomotion path and the accuracy of the calculation depends only on the number of measured input parameters.

For the need of wider use of the indicated dependencies, a large number of experiments were performed for walking in different dispersion environments, in different substrates and in different topographic conditions. For all types of experiments, the step of stride length and two-step length of body height were significant. All measurements showed a higher correlation of the length of two-step to body height than the length of the step-to-to-body height. Linear regressions depending on two variables when walking in different types of substrate are shown in the following table.