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DG/IND/92/404

FINAL REPORT

on the

Foot Measurement Survey in India

Prepared by
OPTIMER HardSoft Ltd,
consulting firm on computer applications

Backstopping Officer: **Dr. Ferenc Schmél**
AGRO-BASED INDUSTRIES BRANCH

Pécs (Hungary), 1999

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Explanatory Notes

CLRI	Central Leather Research Institute at Madras
IILP	Indian Institute of Leather Products
NLDP	National Leather Development Project
UNIDO	United Nations Industrial Development Organization
BSO	Backstopping Officer
CE	Chief Engineer
EXP	Computer Expert
NPM	National Project Manager
AC	Analog Current
AVR	Average Voltage Regulation
BIOS	Basic Input/Output (I/O) System
B/W	Black and White
CPU	Central Processing Unit
CU	Control Unit
DC	Digital Current
DOS	Disk Operating System
DPU	Data Processing Unit
FDD	Floppy Disc Drive
FMS	Foot Measurement System
FMU	Foot Measurement Unit
HDD	Hard Disc Drive
IPU	Image Processing Unit
MB	Mother Board
PCB	Printed Circuit Board
STB	Streamer Tape Backup
UPS	Uninterruptible Power Supply
WFR	Wave Form Regulation

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Introduction

This *Final Report* was prepared under a subcontract awarded to **OPTIMER HardSoft** by the UNITED NATIONS INDUSTRIAL DEVELOPMENT ORGANIZATION (UNIDO) through the project DG/IND/92/404 which has been implemented as part of the *National Leather Development Programme (NLDP)*. The local counterpart agency was the CENTRAL LEATHER RESEARCH INSTITUTE (CLRI) in Madraš (Chennai). This Report provides the complex and most up-to-date know-how for preparation and implementation of foot measurement surveys. Furthermore based on data collected by CLRI staff in India in 1993 a specific example of data processing and sample standards for defining shoe size ranges and designing sample shoe lasts are also presented.

The main objectives of the project were to transfer the know-how required for implementing and to assist in carrying out the *mass foot measurement (anthropometric) survey* in India. The assistance provided local counterparts (CLRI) with equipment, computer software, guidance and training in implementing the foot measurement methodology developed by the Hungarian RESEARCH INSTITUTE FOR THE LEATHER AND FOOTWEAR INDUSTRY (BCK) and its successor organizations (**OPTIMER** and **TechnOrg**) over the last three decades. This method was successfully used in three large-scale foot surveys in Hungary and in a UNIDO project aiming at establishing a shoe sizing standard in Ethiopia.

The survey itself was based on the newest achievements of podology and computer technology including digital video image processing by utilizing high technology equipment and scientific (mathematical statistical and orthopaedic) methods.

The project realized these objectives and from this point of view the project was successful in spite of a great delay. The main results were as follows:

- preparing the technical (hardware and software) conditions necessary to initiate the foot measurement survey by delivering and on site installation of the required instrumentation,
- direct assistance in training of CLRI's representative at Hungary in implementation of foot measurement survey and in using respective equipments,
- direct assistance in training a group of equipment operators at Madras and in conductinga pilot data collection procedure,
- transfer of software suitable for analysis of collected data and to be used to generate the numerical data bases from graphic images,
- training the local counterparts in installation and using of different software,
- direct assistance in analyzing the surveys result and elaborating the parameters of middle size shoes recommended as standards to the footwear size system to be introduced in India,
- elaborating of standardized middle size master shoe lasts designed on the basis of the foot measurement results, as well as documentation on component coordination system reflecting the recommended shoe lasts shapes.

This *Final Report* summarizes these results and in the same time could be used as written documentation and guideline for preparation, performing, analyzing and elaborating of similar foot measurement surveys.

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Recommendations

Specialists of **OPTIMER** and **TechnOrg** have more than twenty years experience in conducting (mass) foot measurement surveys. The technology used in this particular project is based on this extensive theoretical knowledge, lessons learned from measuring several dozen thousands of feet in Hungary and abroad (e.g. in Ethiopia), introduction of shoe last standards in footwear manufacturing companies. The hardware, especially the optical equipment used for taking digitalpictures of feet are of the highest technical level available in the world. The computer software was upgraded and extended to make the data processing as easy as possible, but retaining the high scientific level of mathematical statistical analysis. Staff of CLRI received very detailed instructions on using the equipment and running all computer programs.

In spite of all precautions and safety measures built in the entire system the data collection phase of the project cannot be regarded accurate and reliable enough for making firm and precise recommendations for the shoe sizing system, size ranges and shoe last standard to be introduced in India. The following undisputable facts prove that the actual numeric and geometric results obtained by this survey carry quite some uncertainty:

a) using the information available on the anthropological and anthropometric characteristic of the Indian population the UNIDO backstopping officer in close cooperation with CLRI staffs established the minimum number of feet to be measured in each region of the country but the actual samples do not correspond by their size and distribution to the agreed quantities,

b) due to improper handling of the equipment a great deal of the foot images either were not available or their poor quality - mainly due to improper foot position and distortion of the optical system - do not permit proper data processing,

c) some samples are too small (e.g. in case of adult women), they are not representative so the results derived do not correspond to the reality;

d) girth measurements either were not taken with sufficient care and/or they were simply guessed therefore the sample shoe lasts had to be built on foot width data and they become rather non-proportional;

e) due to the obvious unreliability of girth data sample shoe lasts and their corresponding documentation such as shoe last bottom patterns were prepared on the basis of foot width data (as they are seen and measurable on the foot images), but they become too wide, nevertheless all girths are generally larger by 2-5 width groups then the measured values.

It is **strongly recommended to repeat measurements** paying special attention to sampling, reliability of girths and separating regional or ethnic groups. CLRI is in possession of all equipment and computer software to carry out the repeated survey. Footwear technologists should supervise the survey by checking quantities, data and proportions. UNIDO may consider to employ **OPTIMER** for quality assurance of the survey, to provide guidance as needed, to produce sample lasts and supply additional information on elaborating a shoe component coordination system.

Wherever sufficient data (number of cases with foot images of acceptable quality) had been made available it became obvious that

- there are significant *differences between regions* so their databases should be separated and specific size ranges and grading values are to be derived for each region (during the repeated survey, therefore, it is recommended to test more than four regions: obviously a country with such high population and geographic area has more differences which might be discovered by this anthropometric investigation),
- the *children size group should be broken down* into sub-groups based on consumer behavior and other social features of the local population.

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Based on available and reliable data the recent foot measurement survey made in India led to a very important conclusion: the *proportion (i.e. shape) of feet of the local population differs considerably from what is built in European and North-American shoe lasts*. The main reason is the ethnic (anthropologic) difference between European and American people, but the fact that the overwhelming majority of the Indian population wears open type of footwear (sandals, chappels, slippers etc.) or nothing must have its impact as well. Although substantial differences have been identified between geographic regions of the country it is quite apparent that Indian feet are flatter, i.e. their forepart - especially around the ball and waist part - are wider and lower than in case of European feet. Indian feet have shorter forepart: the distance of ball points from the heel part is relatively larger then that of European feet. The consequences are that footwear made on European shoe lasts do not really fit on Indian feet (i.e. they are not comfortable) and wear off quickly. Further distinction should be between different regions of the country. All this means that **specially designed shoe lasts should be used for footwear produced for domestic sale in India.**

Due to the biological acceleration - which is especially fast in developing countries - anthropometric surveys should periodically be repeated. Since India has large population and a very complex ethnic structure, foot measurement should be extended to various geographic areas to investigate their special features and the deviation from other regions. Technology development also requires more and more refined data for shoe last design and manufacture, for engineering patterns of footwear components and for supply of well fitting shoes for the local population. Availability of comfortable footwear will reduce orthopaedic complaints, prevent development of static foot deceases which will certainly be reflected on the medical expenses of the Government and individuals. It is, therefore, strongly recommended to elaborate a systematic plan for foot surveys to be implemented in the next 5-10 years. Technical assistance provided by NLDP to the Indian rural areas offers a good opportunity to connect them with mini-surveys which will provide useful data for designing and supplying appropriate shoe lasts. By collecting these data a unique information base can gradually be built which provides reliable inputs for comparison of various regions of the country, as well as to supply guidelines for manufacturers and especially retailers regarding optimum size ranges and distribution of sizes when marketing footwear.

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Chapter I

PREPARATION OF THE FOOT MEASUREMENT SURVEY

A (mass) foot survey is a *research programme* based on taking samples of the target population and carrying out certain anthropometric investigations on their feet. Thus it should properly be **prepared** and **planned** with a clear definition of its objective and scope (the flowchart of the entire foot measurement survey is shown on *Figure I-1* on the next three pages). Moreover it has a statistical character since it is impossible to measure each and every person.[1] Like any research programmes foot surveys need some kinds of instruments, staff, methodology for processing the collected data and interpreting results. The preparation of the foot measurement should cover all these aspects.

1.1. The Objective of the Survey

There are two types of foot measurement methods: individual and mass survey. *Individual* foot measurement is used when either a specific foot is analyzed for a specific purpose (e.g. orthopaedic treatment, made-to-measure service). *Mass* or *statistical* surveys aim at assessing size distribution, proportions and determining possible grouping criteria for a given population which may be an entire country (state), a region, a specific group (e.g. children of certain age, soldiers, workers in a given industry, sportsmen). Individual measurements serve a single persons interests, mass surveys try to define characteristics which will be helpful in designing and supplying goods - in our case: footwear - for a given market (segment).

The main objective of this foot survey is to collect data on the anthropometric properties of the Indian population's feet. It is expected that the survey will

- reveal differences among various ethnic groups and geographic areas - if they exist or prove that no differentiation is needed when shoe is produced and supplied to any part of the country,
- determine characteristic age and size groups requiring specific attention when footwear is designed for them,
- set basic measurements to be used for marking sizes of footwear, establish size ranges providing the required coverage of the population with shoes (to be) produced using industrial technology for retail,
- produce rules and numerical data(bases) for designing well fitting shoe lasts which will avoid development of static and other foot diseases caused by wearing not comfortable shoes.

Being part of a technology transfer project this particular survey has one additional, equally important purpose as well: to provide local specialists (namely the CENTRAL LEATHER RESEARCH INSTITUTE - CLRI) with the know-how, equipment and computer software needed for undertaking foot surveys according to local needs.[2]

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[1]Beside economic and time consideration targeting the entire population of even a relatively smaller society (e.g. workers of the heavy industry, skiers) has no practical meaning as the group of people belong to the selected group is a dynamic mass which changes due to mortality, growth and ageing. As a consequence the statistical characteristics (averages, standard deviations, distributions etc.) are in constant change making so while the measurement data are properly processed the characteristics of the population will change - even if this deviation from the measured values are very minor.

[2]Experience of several European countries shows that large-scale anthropometric surveys are required every 10-15 years: within this period of time visible changes take place with regards foot sizes and proportions due to natural biological acceleration. Such changes may take place even faster in developing countries, where civilization, urbanization and increase of leaving standards have a greater impact on the human body and organism, as well as on changing clothing traditions.

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PREPARATIONS AND FOOT SURVEY

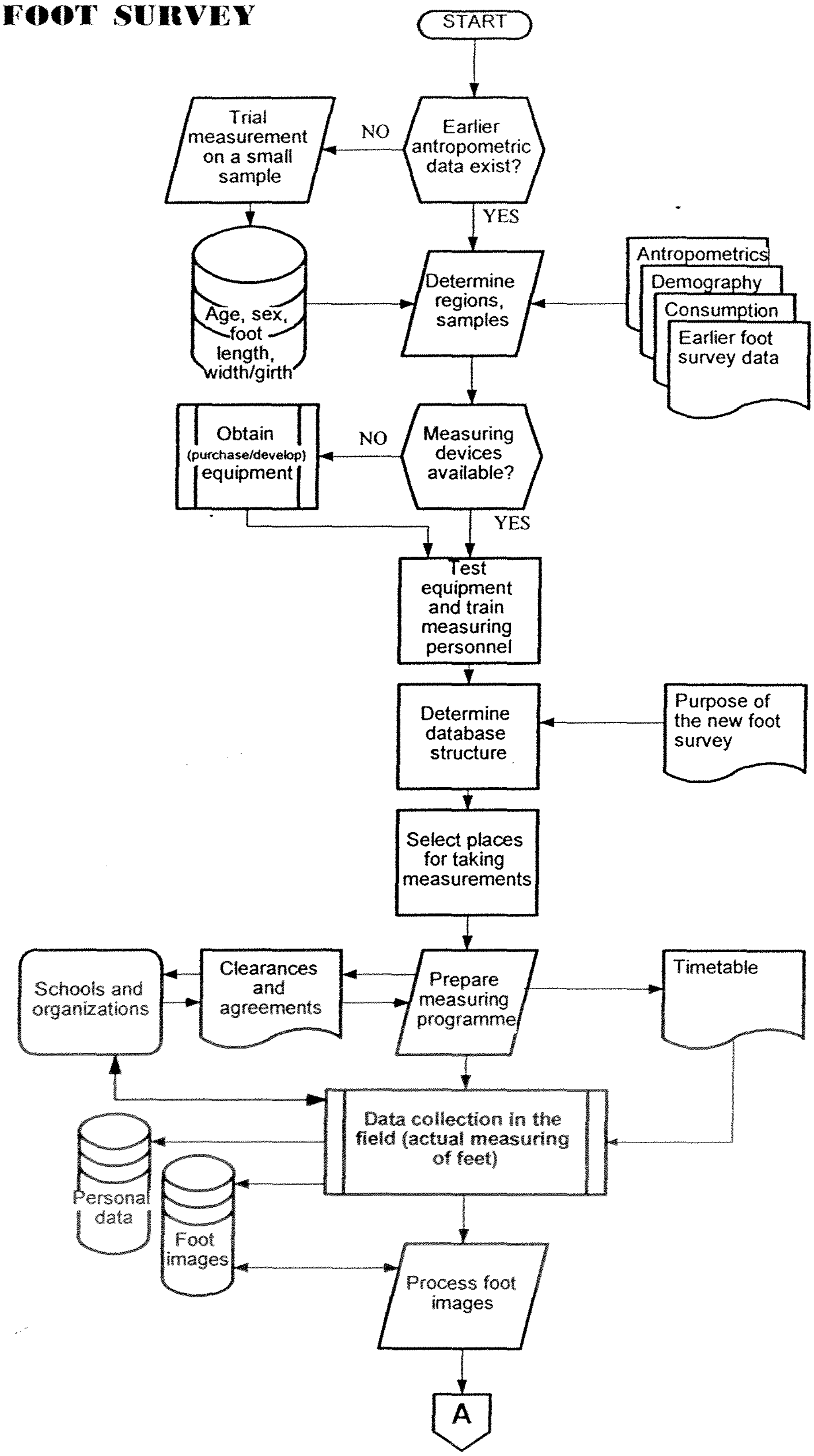

Figure I-1.a

DATA PROCESSING AND ANALYSIS

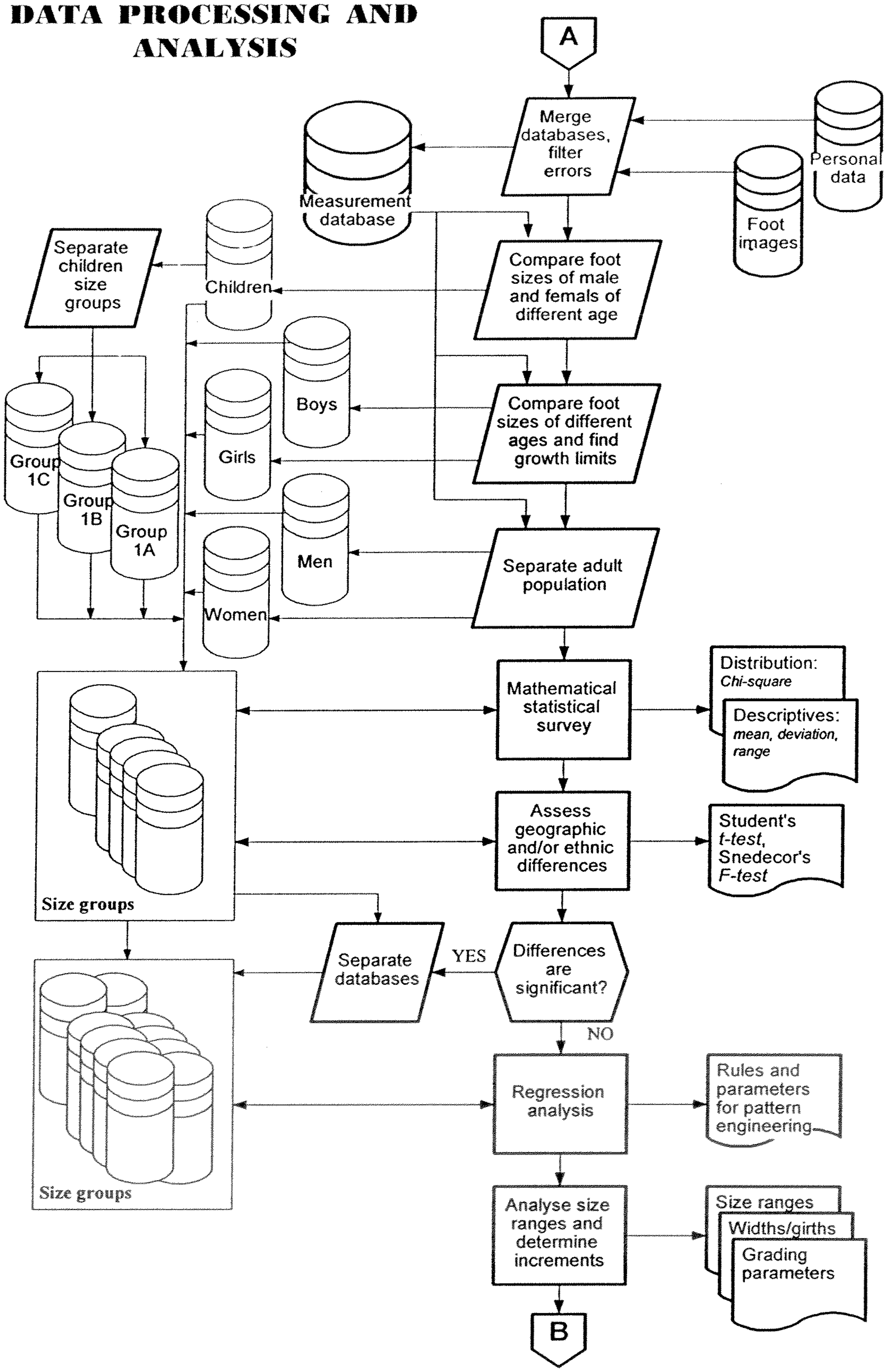

Figure I-1.b

DOCUMENTATION

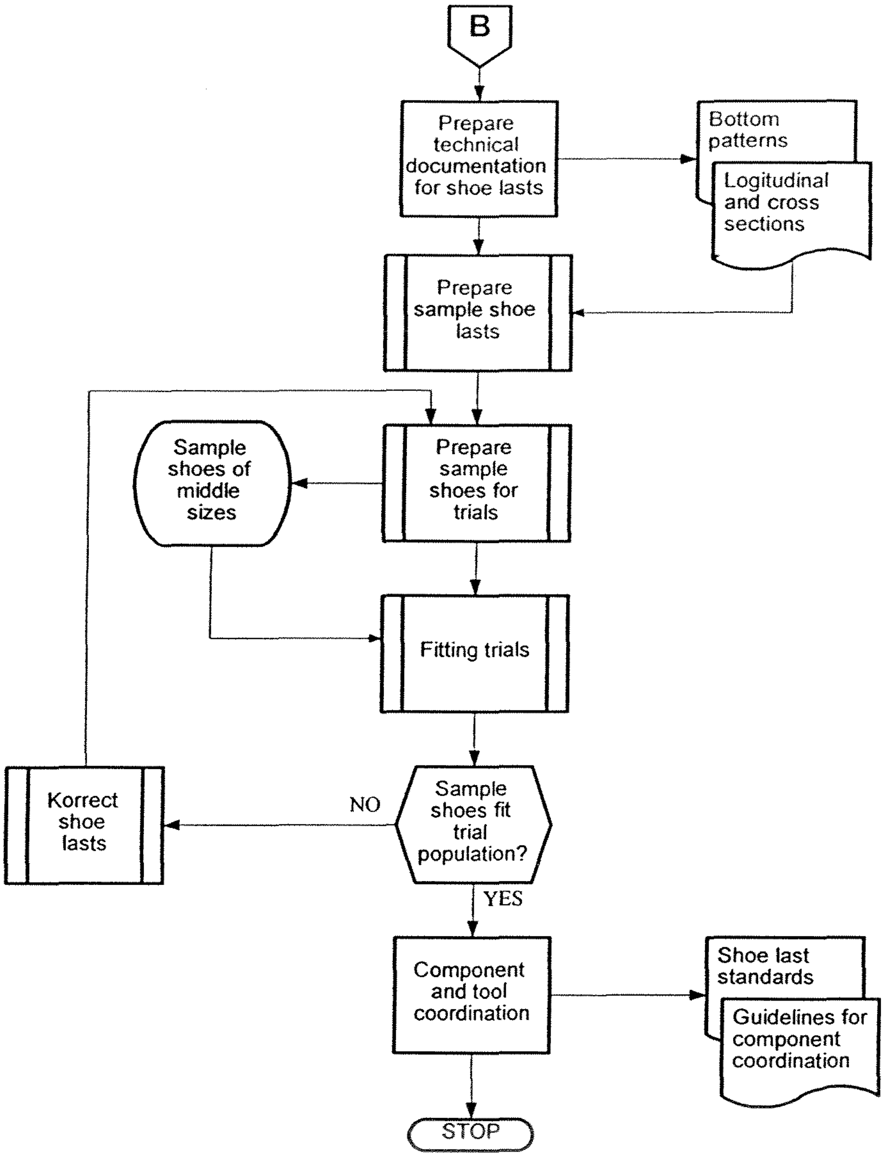

Figure I-1.c
The foot survey process

1.2. Population Groups[3]

1.2.1. General Principles

Adult male and female individuals have visible and measurable differences regarding their body dimensions, but these differences are less or not at all visible among small children. In any case there girls and boys, women and men should form independent groups when conducting an anthropometric survey, i.e. *sex* is a major distinct feature.

[3]This and the following two steps in preparing the foot measurement survey in India was made by CLRI therefore the actual data are not included in this report.

A country's population is normally is a mix of various *ethnic, anthropological* or *geographic* groups of people. Nations, tribes, societies have their native origins in terms of geographic locations. Some of them lived isolated in a given territory (e.g. in islands) for thousands of years and did not have any contacts with other human population. Others had been on constant move (e.g. those making their living from hunting), therefore they had intensive contacts with other ethnic groups. Since certain anthropological and related anthropometric features of the human body is genetically coded, different ethnic groups have fairly characteristic features regarding height, weight, proportion of their limbs etc. As a rule larger countries (states) and those being subject to migration have complex ethnic structures. Therefore substantial differences may be between dimensions of the body (including feet) of people leaving in different geographic regions of the country.[4] Such differences should be known when designing comfortable apparel and footwear and supplying these commodities for the local population. For orientation purpose the literature on anthropology and (or) respective specialists should be consulted. Based on this initial information (ethnic and/or geographic) regions should be determined where feet should be measured during the survey.

Another source of differences between body dimensions of people is their lifestyle - with special references to kind of footwear they wear: this is the *urbanization* effect. Generally speaking urban population wears more (in terms of duration and quantity) closed footwear, while people living in villages, under tropic weather conditions walk and work mostly barefoot or wear some very simple sandals leaving their feet (especially the toes) free most of the time. Unfortunately fashion has a negative impact on foot health (e.g. wearing shoes with pointed toe and/or high heel generate serious problems or even defects needing later orthopaedic treatment. Experience shows that there may be apparent differences between foot sizes, their distribution and especially proportions of urban and rural population.

1.2.2. The Population in India

The most recent attempt to find a system of racial classification is that of B. S. Guha (1938). In Guha's system there are six main races with nine subtypes:

1. Negrito
2. Proto–Australoid
3. Mongoloid
    - a) Paleo–Mongoloid
        - (i) long–headed
        - (ii) broad–headed
    - b) Tibeto–Mongoloid
4. Mediterranean
    - a) Paleo–Mediterranean
    - b) Mediterranean
    - c) Oriental Mediterranean
5. Western Brachycephals
    - a) Alpinoid
    - d) Dinaric
    - c) Armenoid
6. Nordic

The negrito survives in India among the Andamanese, the Kadans and Palayans of Kerala, the Irulas of Wynad, and the Angami Nagas of Assam and the Rajmahal Hills of eastern Bihar. The

[4]It should be noted the size of feet, their form and the arch structure are inherited features. This fact makes even more evident that ethnic groups do have their specialty as far as foot dimensions are concerned.

Negritos were largely absorbed by the Proto-Australoids. Originating in the west, the Proto-Australoids survive in Dravidian tribal populations and are connected with the tribes of Australia. Long-headed Mongoloids represent a more ancient stratum of the population and prevail among the Assam tribes. The round–headed Mongoloids are found in Burma and the Chittagong Hills. Tibeto-Mongoloids are found in Sikkim and Bhutan and appear to be recent arrivals from Tibet. The Paleo-Mediterranean type of medium stature, dark skin, and slight build is found largely in Mysore, Andhra, Chennai, and Kerala. The "true" Mediterranean type is taller and fairer than the Paleo-Mediterranean and occurs in the Panjab and Upper Gangetic valley. This group represents the "civilized" Dravidian people of India who became Aryanized. The Oriental Mediterranean type characterized by a long nose and fair skin is found in the Panjab, Sind, Rajputana, throughout India. Dinaric types occur in Bengal, Orissa, Mysore and Madras. Alpinoids predominate in Gujarat, Armenoids occur in dispersed groups along the west coast, in central India, along the Himalayas, in western Uttar Pradesh and Bihar. The nordic types descend from the ancient Aryan invaders and are strongly represented in the northwest frontier, the Panjab, Rajputana, and the upper Ganetic Valley. They are also represented among high caste groups scattered throughout the country (*Figure I-2*).

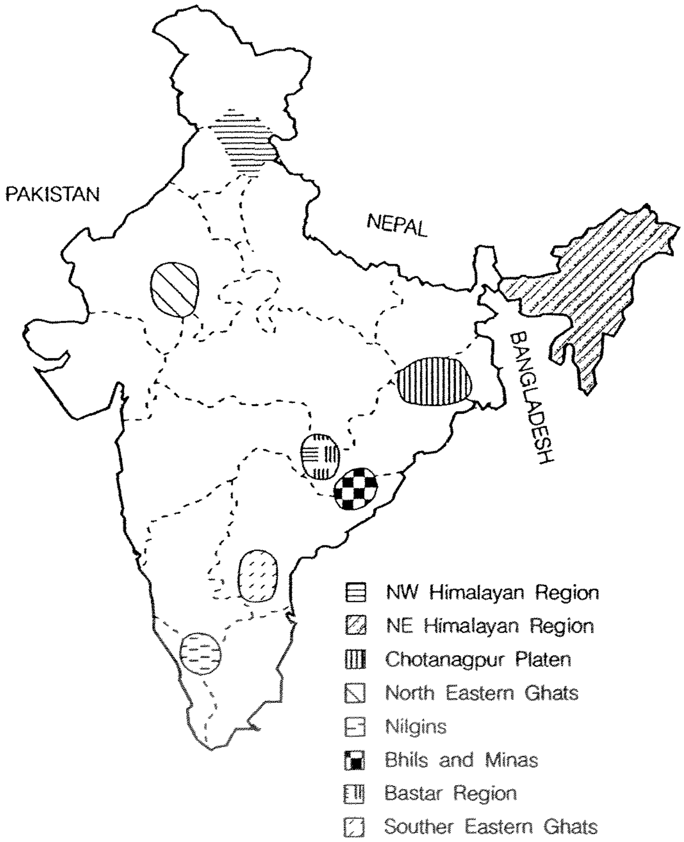

Figure I-2.
Tribal areas in India.

1.3. Sample Sizes

The sample is relatively small group of people which will be measured during the survey. Since not every foot in the given population will be measured a certain *error* is expected from the investigations (assuming a normal distribution of foot measurements):

$$|d| = \frac{\lambda\sigma}{\sqrt{n}}\sqrt{1 - \frac{n}{N}} \qquad \textbf{(I-1)}$$

where d is the absolute value of the error due to the sampled survey, λ is a coefficient depending on the confidence level of the statistical investigations, σ is the variance of the(main) measurement, n is the sample size (number of feet measured), N is the size of the population (total number of individuals). Normally the sample is much smaller than the population, i.e. $n \ll N$, therefore

$$\sqrt{1 - \frac{n}{N}} \approx 1 \qquad \textbf{(I-2)}$$

Substituting this into equation (I-1) and taking into consideration that the best estimate for the variance is the standard deviation (s), after elementary transformation we receive:

$$n \geq \left(\frac{\lambda s}{|d|}\right)^2 \qquad \textbf{(I-3)}$$

The latter formula indicates that size of the sample depends on the targeted confidence level (λ), the degree of deviation within the measured dimension (s) and the permitted absolute error of the survey (d), but it *does not depend on the size of the population.*

In practice anthropometric surveys are made at 90% confidence level[5] for this λ=2. The value of the standard deviation may either be taken from the latest similar survey or by taking an a very small sample(30-50 people) and measuring only the most significant dimension: the length of feet.

The total error should not be more than the unit of measurements used for expressing the characteristic dimension of the foot. Since the smallest unit is a half English size[6] $d \leq 4.23$ mm. We should differentiate the physical error - in our case it is ±0.5 mm, so the total error of the statistical investigation should be $d \leq 3.23$ mm, i.e. the absolute error should be $|d| \leq 1.63$ mm.

Certain compromises may be required when setting the size of samples (e.g. if too many measurements are taken and the process is too slow or laborious). On the other hand some reserve should be made (i.e. the actually number of feet measured should be somewhat higher then the computed minimum requirements as there may be errors, incomplete data or the feet may be of not "normal character").

1.4. The Measurement Programme

After having determined and selected the characteristic geographic areas and having computed the minimum sample sizes appropriate places should be selected for taking foot measurements. The more people is accessible in one location the more suitable is the given organization for undertaking part of the survey. In case of children and youths kindergartens and schools are natural choices as a large number of individuals can be handled in an orderly manner. Army stations (barracks) are another places where measurements can be

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[5]See paragraph 5.4 for a detailed explanations.

[6]For details of different foot measurement systems and units see *Chapters III* and *IV*.

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carried out efficiently. The most difficult thing is to find organizations or companies where a large number of adult female feet can be measured.[7]

Administrative *arrangements* should be made with authorities (management) of the selected locations and organizations. This should cover timing, organization of flow of individuals, provision of a suitable place for setting up measuring devices and (portable) computers for data collection. Finally a thorough travel programme should be prepared - again with reserves to cover unexpected losses in time (e.g. breakdown of devices, transport problems). It is important to take into consideration local or national holidays to prevent unproductive time during the survey.

1.5. The Measuring Technology

The measuring method may range from a fully manual to a well mechanized approach. The *manual* (or traditional) methods are based on drawing the plantar projection of foot on a sheet of paper and taking its dimensions using simple tools such as liners or measuring tapes. Semi-mechanized methods use plantograms or mechanical devices for determining dimensions of feet. The *modern measuring technology* takes advantage of high-tech optical, electronic and computer technique. The technology together with the objective of the survey influence also the number and distribution of measurements to be taken from each person (see below).

In case of the foot survey made in India the most advanced computerized photometric method and respective equipment were used (it is explained in detail in *Chapter II*).

1.6. Database Structure

The photometric method registers two orthogonal projections of each persons foot or feet in digitized form on magnetic data storage device of the computer. The plantar (bottom) and the side views of feetcan later be displayed on the computer screen and be analyzed to the required details (see *Annex A*). Beside these graphic data other characteristics such as sex, age, geographic location, body height and weight etc. should also be recorded.[8] Since perimetric data such as ball, waist, heel and ankle girths are indispensable measurements for shoe last and footwear design, they should also be taken (manually) on the spot.

The set of primary data to be collected on the spot should be determined as there will be no chances to collect missing data at later stages of the survey. (The set of data collected during the foot survey in India are included in *Annexes B* and *C*.)

1.7. Measuring Conditions

The most important condition of the body position of the person while the images of his/her foot projections are taken by the digital cameras, as well as when girth are measured. The person should stand on both feet, whereby the two feet should be placed parallel approximately in a distant equivalent to the shoulder

[7]Traditions and religion may be additional burdens to find suitable places for surveying the female population feet.

[8]Foot surveys may be combined with other research works (e.g. collecting main body measurements required for [leather] garment manufacture, orthopaedic screening).

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span (width), why the body weight should be equally distributed between the two feet. It is sufficient to measure only one of the person's feet, so the right feet were measured in this survey.[9]

Mass surveys should be restricted to people having healthy feet, i.e. who's feet do not suffer from orthopaedic diseases, the differences between left and right feet are not visible in the first site, the person can walk and run without any difficulties. A special (orthopaedic) surveys may be launched to analyze orthopaedic deviations from normal feet, but these serve medical purposes rather than industrial.

[9]Experience shows that the left foot of nearly ⅓ of the population is larger then the right one, in case of another ⅓ it is other way round, why ⅓ of the population has more-or-less equal feet (i.e. the differences are within the physical or practical error of measurements). The objective of the foot survey may be extended to verify this assumption: in such case both feet are measured and they are compared using appropriate mathematical-statistical methods.

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Chapter II

FOOT MEASUREMENT INSTRUMENTATION

2.1. System History

The *Foot Measurement System* (FMS–II)[10] is the new, substantially enhanced version of the methodology and scheme elaborated and successfully implemented by the Hungarian RESEARCH INSTITUTE OF LEATHER AND FOOTWEAR INDUSTRIES[11]. This new system has been created by **OPTIMER HardSoft Ltd.** in close cooperation with footwear technologists of **TechnOrg Consulting Ltd.** and orthopaedic specialists. It is used for podology studies, i.e. foot surveys aiming at assessing special geometric and orthopaedic properties of one person's feet, as well as for carrying out mass measurement programs to establish size ranges and shoe last standards for a footwear company or even for the customer population of a state or a region. It can be used in research, surgical shoe manufacture, made–to–measure services, retail studies, medicine, demography, criminology etc.

The FMS–II consists a set of high–tech equipment and specifically designed computer software, coordinated by a well elaborated system (methodology). The second generation of the **Foot Measurement System** was ised in India under the atechnical assistance project implemented by UNIDO through the *National Leather Development Programme (NLDP).*

2.2. The Measuring Principle

The human foot is complex three dimensional living object covered by free form surface, which changes its exact dimensions during walking, by changing the human body's position, by the time and age. The shoe last, the very basic tool used in shoemaking is in fact a model (representation) of feet - a kindof average of the given person's or population's feet. Fit and comfort, i.e. consumers' satisfaction - as well as design and pattern engineering, tooling of the production, component supply (coordination) all depend on the successful design of the shoe last. For this purpose very accurate data are required on the geometry of foot.

The hart of FMS–II is a high precision, fully automated equipment capable of capturing image of the human foot in form of orthogonal projections. These images are stored and later processed by finding their boundaries, determining linear measurements and typical angles according to a predefined network. Along with the foot shape a set of body characteristics (e.g. age, weight, height, working conditions, geographical region) are registered by the system. These data are used for the sophisticated mathematical–statistical analysis of the given or selected population. Based on the results of earlier mass foot measuring projects led by UNIDO, the program system of FMS-II applies an essentially new method for data sampling. This method is the video digitizing.

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[10] "Series II" indicates this is the second generation of the photo–optical foot measurement system developed in Hungary.

[11] BŐR– ÉS CIPŐIPARI KUTATÓ–FEJLESZTŐ VÁLLALAT (BCK) having names as BŐRIPARI KUTATÓ INTÉZET (BKI) and BŐR–, MŰBŐR- ÉS CIPŐIPARI KUTATÓ INTÉZET (BMKI) in 1970's and 1980's respectively.

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Two video cameras are monitoring the measured object from orthogonal (bottom and side) positions. The live pictures are grabbed and digitized. The digitized data are stored as "picture-files", ready for later computer procedures of data retrieve. These procedures have to include the transformation of pixel-graphic picture-file into a vectorized data stream describing the contour of shapes. The curve of this contour could be analyzed by mathematical methods and any measuring data, e.g. sizes, distances, angles could be retrievedfrom the computer.

2.3. The Hardware

The data collection hardware of the FMS-II consists the *Foot Measurement Unit (FMU)* and a set of portable microcomputers controlling the image capturing and data collection process (*Figure II-1*). The FMS-II is portable, so data collections related to determining shoe size ranges, children feet variation by geographic regions or age groups etc. can be carried out on the spot with minimum efforts wasted in setting up the system.

The FMU looks very much as a trunk - in fact the lighting and the primary image capturing devices are mounted in a sturdy, inside well padded luggage providing reliable conditions for transporting. When opened shields surround the heavy glass surface where a foot is placed and the person can put all or portion of his/her body weight on that feet. The foot projections appears on the screen of the *Image Processing Unit (IPU)*. The light sources are halogen lamps armed with special colored filters. The amount of lights used in image capturing process is set from the *Control Unit (CU)* linked to the IPU. Two *digital cameras*[12] also controlled by the IPU through the CU capture the projections of the foot. After havingensured that the picture quality meets the quality requirements the image is saved on the hard disk of the IPU. The image files may be copied to a backup drive as well.

The *Data Processing Unit (DPU)*, in fact a portable computer is integrated into FMS-II to collect personal data entered through its keyboard and/or collected from the optional electronic devices such as a balance to take body weight and a height measuring unit. Both the DPU and IPU are equipped with barcode readers to take the identity numbers assigned to the persons measured (these are especially useful in mass measurement surveys in developing countries, where unique labels are attached to each persons).

All hardware components are portable, moreover they are mounted into a comfortable *transport system* which also serves as stands during the measurement process. The complete FMS-II can easily be placed in the booth of a personal car. The entire system is connected to the source of electric power through the *Universal Power Supply (UPS)* providing cantonese and stable power for each unit integrated in the system (this is again useful in rural areas and developing countries where the power supply is unreliable).

2.4. The Firmware and Software

The FMS-II consists of four packages of computer programs. The FootGrab program *controls the image capture process:* takes the identity number (from barcodes or from the keyboard), sets the amount off lights and controls the digital cameras through the CU, stores the images on harddisk and produces backups on tape. The FootDat program takes also the identity number, *collects personal data* keyed in through the keyboard or received from measuring devices - all in standard database format.

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[12] FMS–II has two digital cameras in its present version producing two views: the plantar (bottom) and the side projection of the foot. The system can be extended by adding one more camera and the corresponding light sources to produce the third orthogonal projection, i.e. the heel (back) view.

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A separate programmed package FootProc is designed for *processing images* stores on tapes. The views of feet are brought to the screen[13] then linear measurements are taken from it. The view contours and a set of these measurements such as foot length, distance between the heel and the small toe, heel and forepart widths, toe angles and heights etc. are captured automatically. Furthermore the operator may take any additional linear measurements and angles using the mouse of the system. All this numeric information is added to the database consisting personal data.

The *mathematical analysis* of all collected data is made by the fourth computer programs FootStat. It sorts data, create groups (e.g. age, geographical regions, occupation), computes statistical parameters, carries out correlation and regression analysis and it consists and optional cluster analysis module. The results include age and size groups, recommended size grading parameters for various sizing systems, data to be used in shoe last and footwear design and pattern engineering. The "byproduct" produced by the system is a set of information which can be useful in orthopaedics, demography, anthropology, ergonomy, criminology and many other areas of the science and technology.

All the above mentioned modules are interactive, menu driven and produces a variety of printed and plot output.

2.5. Composition of the System

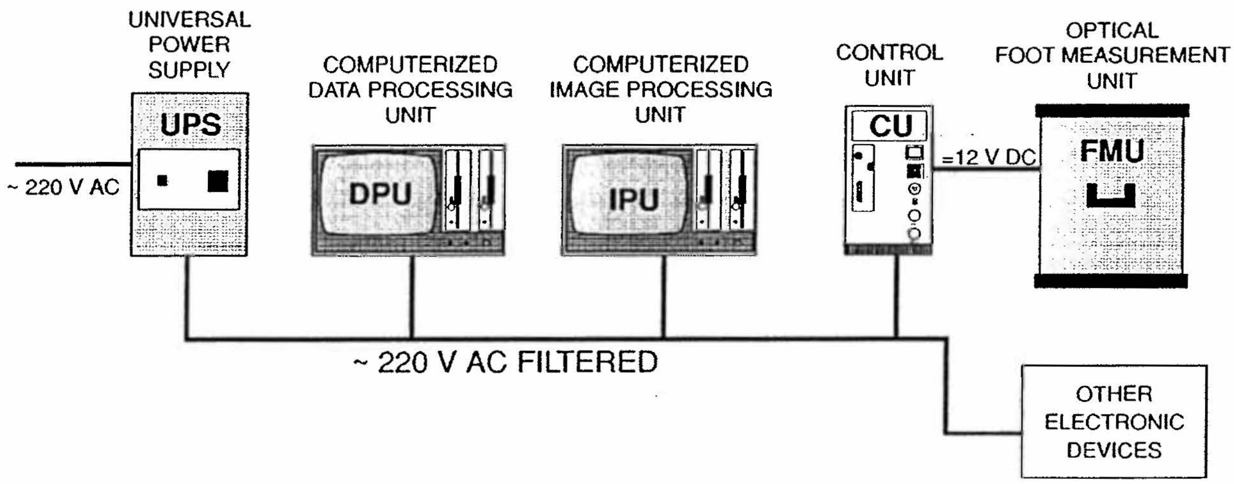

Figure II-1. Structure of FMS-II

The ***Technical Reference Manual*** describing hardware structure of each components of FMS-II is attached as *Annex D.*

[13]The hardware used for image processing is a high speed standard personal computer consisting an Intel® 80486 microprocessor (if possible with 55 MHZ or higher), 8 MByte RAM, 120 MByte (or larger) HDD, 1.44 MByte FDD, Streamer drive, VGA monitor, keyboard, MS® mouse, MS-DOS® 5.0 and MS-Windows® 3.1 (or later). This hardware is not supplied with the FMS-II.

Chapter III

FOOT MEASUREMENT SOFTWARE SYSTEM

The hardware system described in the previous chapter and in the *Annex D* is operated by using the unique software especially designed for this application. The software system of FMS-II supporting the whole measurement procedure consist of two groups of programs: the data collection programs and the data processing programs. The data collection programs were designed to run on the computerized Data and Image Processing units of FMS-II during the data collection procedure. The processing software were designed to run on analyzing computer systems, which have to be greater capacity and more powerful computer configurations.

3.1. Data Collection Programs and Procedures

The data collection is the organized and partly automated procedure of capturing and storing the prescribed data from a sample population of people selected on a random way in statistical meaning. The collected data are foot-related, body-related, personality-related. The most important are the foot-related data, measured automatically by FMS-II. Some foot-size values are measured manually for control purposes. The body-related data are measured manually also. All the other data are issued as answers given by executed person during measurement. The investigated person are identified with bar codes also automatically entered. Thus the data collection programs have to manage automatically captured graphic images, measured numerical values, bar code values and manually entered values. The target is to transform all input data into common numerical databases.

3.1.1. Numerical Data Collection Program

The numerical data collection is controlled by program FootDat. The program FootDat is an executable program written in database language FoxPro. Its task is to support the input data flow and to save the captured data into databases of given structure. Information handled by the system is arranged in three master, four slave and two utility databases having the following file names (for database structures see *Annex C*):

- Masters: DATA1.DBF, DATA2.DBF, DATA3.DBF
- Slaves: PROFESSI.DBF, WORKING.DBF, LOCATION.DBF, DUCATIO.DBF
- Utilities: SEGIT.DBF, SETUP.DBF.

Master databases are related through field named CODE. The manually measured data set was distributed for three parts to give the possibility for partial measurement. The feld CODE is a 13 digit numeric value automatically received from the bar-code reader unit. This number satisfies the bar-code standard EAN-13 by automatic generation of 13th (control) digit from the first 12 ones. Each measured person receives two consecutive bar-codes: the first 12 digits create consecutive numbers and the 13th digits are different. The first bar-code will be used during FootDat procedure and the second one during FootGrab measurement.

Slave databases contain the different nominations applicable as choices when entering answers into master database DATA2.DBF. The number of these nominations could be increased during a measurement, therefore the contents of these slave databases could be changed in a separate data maintenance part of the program (supplement files). The menu-like choice appearing when selecting an answer for question about profession, education, working or location can be modified. The operator is able to insert new values, but deleting for already used categories is not allowed.

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Utility databases are not used during normal operation, but those are necessary for installation and error handling of FootDat.

The purpose of **numerical data collection** procedure is to open a new data record for each measured person and to store the collected data into computer storage for later investigations. The first moment of this procedure to assign a CODE (a pair of bar-codes) to the given person. Reading the first bar-code will open a new record, then the operator can start to enter the measured data values (DATA1). The next step is to enter the personality related data (DATA2) if answers are available. In this case the answers typically could be selected from submenus of possible answers (e.g. different kind of professions, education, etc.). The final input group are the optional body-related (apparel) data which are stored into DATA3 database. Program FootDat realizes all these input tasks with specific functions and also provides on the necessary support functions.

Program **functions of FootDat** are realized through a menu system, thus the overview of menu system gives the list of program functions as well.

MEASUREMENT — Function group of measurement data input.

- *ADD* — Add new person (and data set) to database and enter shoe-related data (fields of DATA1.DBF).
- *OPTION/SHOE* — Enter optional personality-related data (fields of DATA2.DBF) of actual person.
- *OPTION/APPAREL* — Enter optional body-related data (fields of DATA3.DBF) of actual person.
- *RETURN* — Back to the previous level of menu.
- *DATABASE* — Activate database handling function group.
- *NEXT* — Jump to next data record in database (next person).
- *PREV* — Jump to the previous data record in database (previous person)
- *SEEK* — Looking for data record of given CODE identification.
- *EDIT* — Edit actual data record in database.
- *DELETE* — Delete the actual data record in database. This function deletes all data records of the person (DATA1, DATA2, DATA3) related to actual CODE ID.
- *GOTO* — Jump to the data record given by a serial number.
- *TOP* — Jump to the first data record in database.
- *BOTTOM* — Jump to the last data record in database.
- *NUMBER* — Jump to the data record given by its physical RECNO.
- *RETURN* — Back to the previous level of menu.

LIST — The function group of system list outputs. Different lists could be generated using this function about main data (DATA1), optional personality data (DATA2) and optional body data (DATA3).

UTILITY — The function group of setup and maintenance procedures of program.

- *INDEX* — The data records marked logically for deleting will be deleted physically, and new index files will be generated.
- *PACK* — Physical erasing of data records marked for deleting earlier.
- *SUPPLEMENT FILES* — Maintenance function of slave databases. Operator could maintain using this function the following data:
  - Profession
  - Mode of working
  - Location (region+city)
  - Education
- *DRIVE* — Operator can setup the data path using this function.
- *SAVE DATA* — Operator can save the measured data to floppy discs.
- *LOAD DATA* — Operator can load earlier measurement from floppy discs.

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QUIT — Exit from program FootDat. This function could be activated also by pressing keys CTRL + X simultaneously.

The flowchart of the FootDat program is shown on *Figure III-1*.

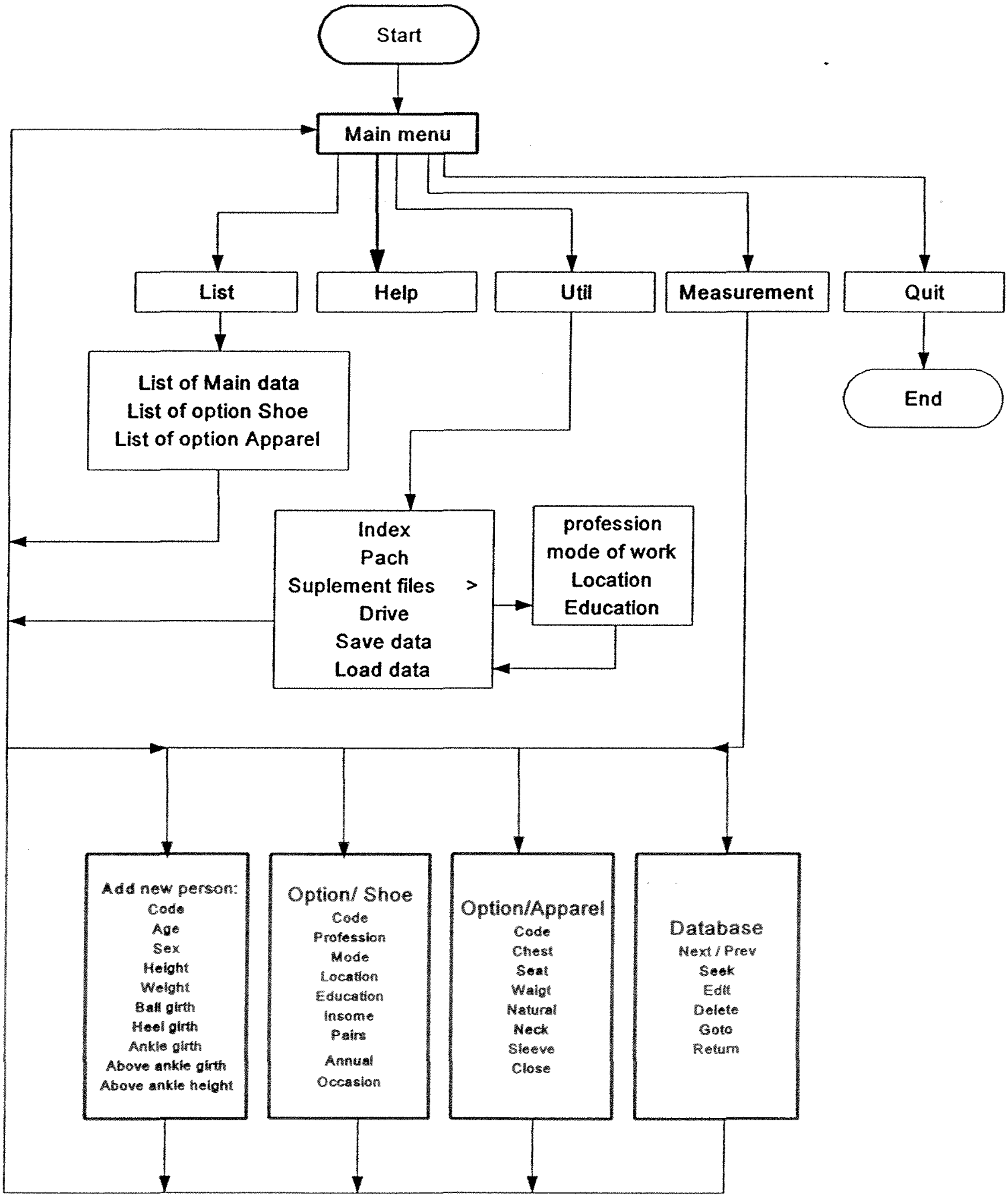

Figure III-1. Floowchart of the FootDat program

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3.1.2. Graphic Data Collection Program

The task of graphic data collection is to retrieve a set of visual "picture" information about a foot, to convert them into numbers having geometric meaning. This procedure substitutes the difficult and slow piece-by-piece manual measurements using up-to-date computer programs and methods.

Overview of Measurement with ***FootGrab***

As mentioned earlier the human foot is a complex three dimensional object containing both convex and concave surface elements. It would be very difficult to collect the necessary numerical data describing a foot by traditional manual measuring methods. Based on the results of earlier mass foot measuring projects led by UNIDO, the program system Foot applies the essentially new method for data sampling. This method is the video digitizing. Two video cameras are monitoring the measured object from orthogonal (bottom and side) positions. The live pictures are grabbed and digitized. The digitized data are stored as "picture-files", ready for later computer procedures of data retrieve. These procedures have to include the transformation of pixel-graphic picture-file into a vectorized data stream describing the contour of shapes. The curve of this contour could be analyzed by mathematical methods and any measuring data, e.g. point coordinates, sizes, distances, angles could be retrieved from the computer.

The program realizing the data collection functions of above described procedure named FootGrab. Its basic task is to take "computer-photos" i.e. to capture pictures of the foot from two point of views.

The two graphic files created by the program are named according to the bar-code identifier related to person actually measured. FootGrab provides a set other functions related to the hardware-software connection between the measuring equipments (IPU, CU) and the computer. The hardware video interface card receives the video signals from two separate video channels: one for bottom view and one for side view. Only one video channel could be active in the same time, therefore the computer have to provide on the selection of proper video channel. It is done automatically by FootGrab.

The light sources are two pairs of 12V halogen lamps. These lamps are controlled also automatically according to the actual video source. It is possible to regulate the intensity of light as well.

The digital picture's photographic parameters are also easily adjustable from the program. These are the brightness and the contrast parameters. The proper setting of light intensity, brightness and contrast could result the characteristic digital photo, being necessary for valuable postprocessing of pictures. The setting are always stored, thus the program starts with the last settlement as defaults.

The Captured Graphic Image Files

The "computer pictures" received from the application of FootGrab are so called "bit-map" files. This is a common method for digital storage of graphic objects. The practical essence of this method is based on distributing the whole picture for rows and columns with a given resolution. The small object belonging to one row and one column index will be named as "dot" or "pixel." The number of such dots per inch (DPI) will characterize the quality of resolution. Each pixel are qualified withone ore more bits representing the pixels's darkness or color. These bits of unique pixels collected e.g. in a row-by-row system and joined into a digital data file are creating the so-called "bit-mapped" digital picture. The interpretation (reading and displaying) of such picture equals with the point-to-point analysis of the bit-mapped file according to its built-in system (e.g. row-by-row) and replacing the bits with their meaning (gray shading or color).

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There are a large variety of standardized methods for bit-mapped and compressed storage of pictures. And there are conversion methods as well to convert one standard format to another. The most familiar picture formats are identified by their special file-name extensions, e.g. PCX, PIC, GIF, BMP, TIF etc.

The picture specifications applied in FootGrab are described below:

Format standard:	.BMP (Windows standard graphic file format)
Resolution:	640 x 400 pixels
Colors:	256
File size:	256 K

A pair of pictures grabbed from a sample foot shown on the following figures:

Figure III-2. Bottom view

Figure III-3. Side view

3.1.4. Graphic Data Collection Procedure

The graphic data collection is the most important part of a survey(he procedure is described on *Figure III-5*). The measurement usually are not repeatable later. The operators of FMS-II have to prepare carefully each measurement series by performing test measurements. The test measurements are necessary also to calibrate the measurement unit for modifying the transformation parameters when using FootProc during final processing of pictures. The operating parameters also have to be adjusted according to environmental changes (e.g. increased external light) or object changes (e.g. different skin colors).

The measured persons are identified by two consecutive bar-codes. The files created by FootGrab are also using these codes: the files are identified with the middle 11 digits of the two bar-codes. In both cases the first digit is omitted, the next 8 digits will be the file name and the next three digits are the name extensions. Thus the picture of bottom view will have an even extension and side view will have an off extension.

The size of pictures relatively large: 2 measurements = 4 pictures = 1 MByte. Therefore the storage of pictures on hard drive is limited. The solution is the application of digital tape drive subsystem built into graphic DPU. This unit is capable to store 250 or 500 complete measurements. Using the attached special backup software the contents of hard drives have to be copied regularly to digital tapes, releasing free spaces for new measurements.

Using the FootGrab Software

The application of program FootGrab requires the units IPU, CU, FMU. The different units All the available functions are single-key activated without using menu structure. This method supples the quick adjustment, sampling and archiving necessary for mass foot survey.

The HELP-key is **F1**. Pressing this key will result to display on the screen a list summarizing the active function keys and their effects.

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There are two basic methods of using FootGrab. One is the *interactive method*, when each step of procedure have to be initiated by pressing the proper function keys. The other is the *automatic method*, when a single key performs the whole procedure without additional interactions.

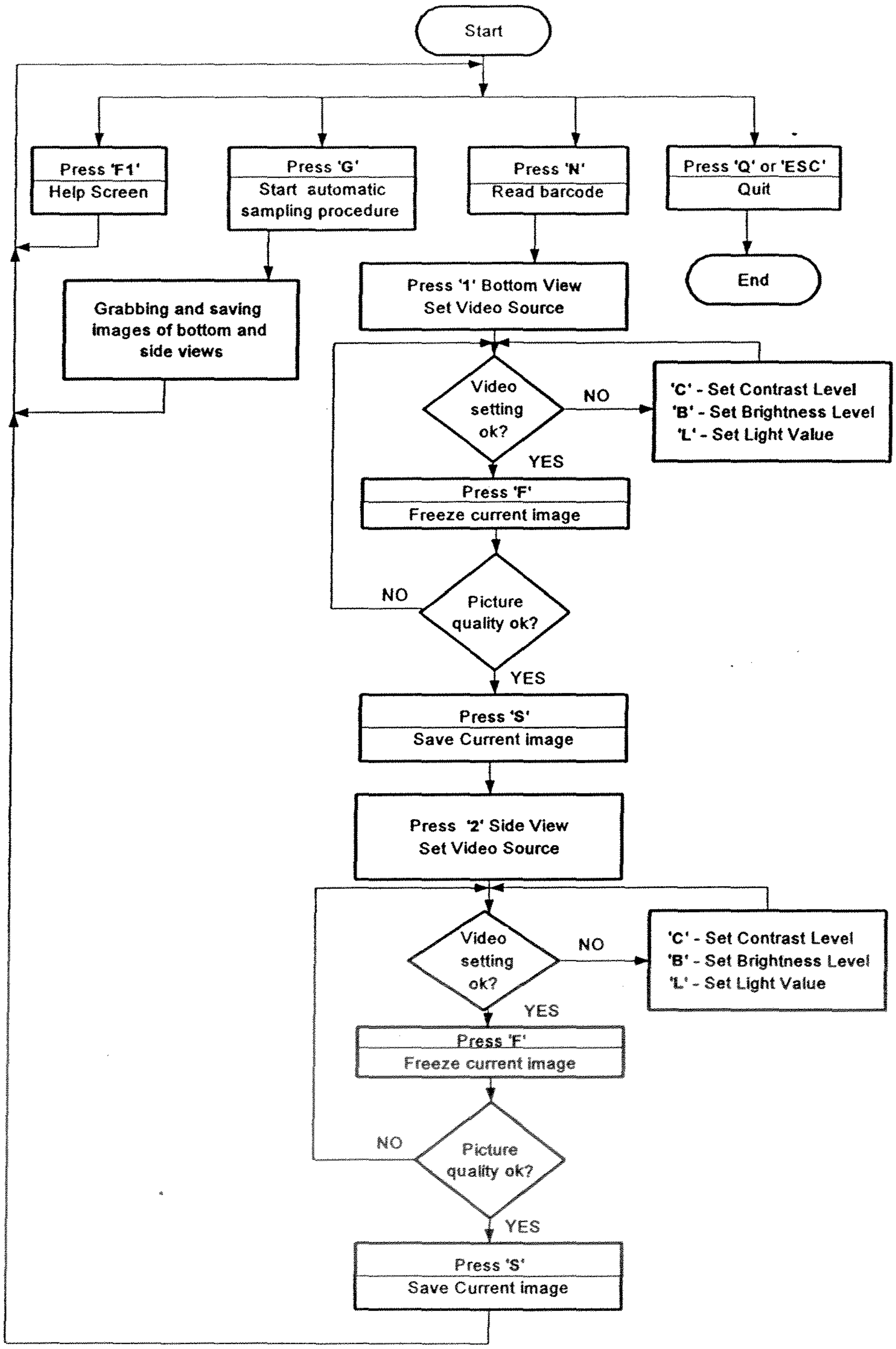

Figure III-5. Flowchart of the FootGrab program

The Key–commands of ***FootGrab***

F1 **Help**
This function gives you the list of the program's functions and its hot keys. Press any key to exit Help.
Message: The whole help screen

1 **Switch to video channel #1**
After pressing this key the first video channel and appropriate lamps will be activated and the bottom view appears on the screen.
Message: Video source: bottom view

2 **Switch to video channel #2**
After pressing this key the second video channel and appropriate lamps will be activated and the side view appears on the screen.
Message: Video source: side view

F **Freeze the Picture**
After pressing this key the online digitizing process is frozen and the static picture could be analyzed on the screen. Press any key to return to online process.
Message: Image frozen.

N **Assign Barcode**
After pressing this key the barcode to be used for saving could be inserted in 13 decimal digit format. This can be done from the keyboard or with a Barcode reader device. ***The 12th digit must be an even digit.***
Message in upper right corner: the entered number (see screen photo on *Figure III-5*).

S **Save the picture**
This key is applicable for saving the screen's contents into a file. The file name generates the program from the entered 13 digit Barcode number with the **Assign Barcode** function. This function doesn't needs the picture to be froze, after pressing the "S" key the freezing will be done automatically.
Message while saving: Saving image to xxxxxxxx.xxx, please wait...

B **Setting The Brightness**
This key turns the keyboard to setup mode. The arrow keys modify the brightness value in range 0-256. For up/down keys the increment/decrement is +1/-1, for left/right it is +10/-10. Press Enter key to return.

C **Setting The Contrast**
This key turns the keyboard to setup mode. The arrow keys modify the contrast value in range 0-256. For up/down keys the increment/decrement is +1/-1, for left/right +10/-10. Press Enter key to return.

L **Light intensity setting**
This key turns the keyboard to setup mode. The arrow keys modify the intensity value of the lamps belonging to the actual video channel in range 0-16. For up/down keys the increment/decrement is +1/-1. Press Enter key to return.

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G **Go and start sampling procedure**
This key activates a procedure containing a series of stand alone functions detailed above. This series is:

1. Read barcode as file name #1	(Function **N**)
2. Select camera and lamps #1	(Function **1**)
3. Freeze picture	(Function **F**)
4. Capture and save bottom view	(Function **S**)
5. Generate file name No.2	
6. Select camera and lamps No.2	(Function **2**)
7. Freeze picture	(Function **F**)
8. Capture and save side view	(Function **S**)
9. Return to online mode	

Message: Video source: bottom view

Q **Quit to DOS prompt**
After pressing this key the program will save the values of settings, and returns to main menu. The "**Esc**" keystroke will cause the same result.
Message: Video source: bottom view

Error Messages

Internal video error
Reflects to an internal system error. Leave the program, restart the computer with RESET key. Start again Foot and FootGrab from main menu. If the error message still appears, please contact **OPTIMER**.

Disk full
Too many graphic files were saved to hard drive. Leave the program, start TAPEBACK from main menu, backup all unnecessary data files to cartridge. Start again Foot and FootGrab from main menu.

Invalid Barcode
The string given as barcode is invalid. Check whether its length is 13 digits. Check whether the 12th character is even. Enter the proper barcode again.

3.2. Graphic Data Processing Programs and Procedures

The task of graphic data processing is to analyze the graphic images, to perform the necessary conversions (mathematical transformations) and to produce numerical data,i.e. numbers describing the measured foot. This analysis have to be performed on a great amount of images created by the program FootGrab during the first, data collecting phase of the this survey project.

3.2.1. Graphic Image Correction Procedure

The program designed to perform automatically these analysis and transformations is program FootProc. The successful application of this program requires good quality graphic images satisfying a set of different photometric and geometric conditions. In case of good application of FootGrab these conditions are provided automatically, but in case of any misuse of grabbing equipment and program the resulted pictures should be incompatible with program FootProc.

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Using Paintbrush to Repair Pictures

To disclose these incompatibilities the picture-pairs have to be supervised before final processing. For this purpose any kind of graphic editor with ability ofbitmap editing could be used such as PaintBrush, available e.g. from Windows *Accessories* group. After starting the program select *Options* and *Image Attributes* to prepare the image format described earlier in paragraph 3.1.3. Set up the following values:

Unit	pels	(pixels)
Width	640	(640 pixels/each row)
Height	400	(400 pixels/each column)
Colors	colors	(256 colors/each pixel).

Figures III-5, III-6, III-7, III-8, III-9 and *III-10* illustrate the image correction procedure.

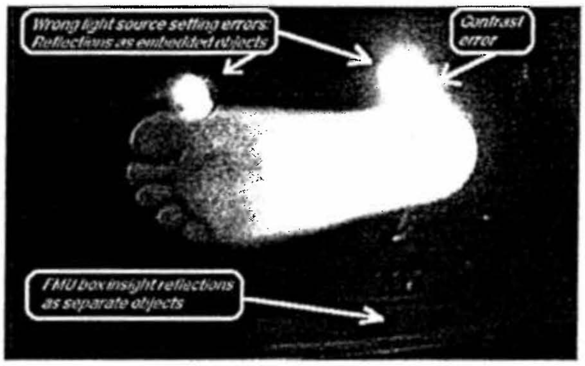

Figure III-6. Bottom view before correction

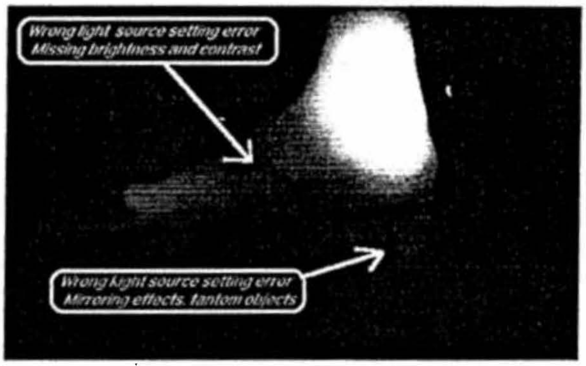

Figure III-7. Side view before correction

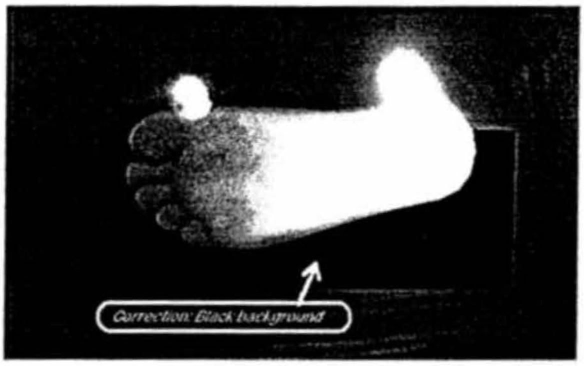

Figure III-8. Correction Phase Bottom View

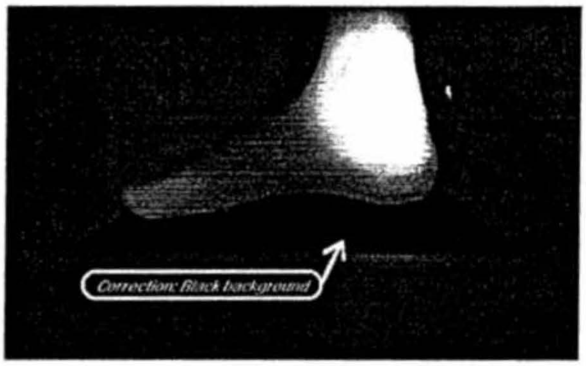

Figure III-9. Correction Phase Side View

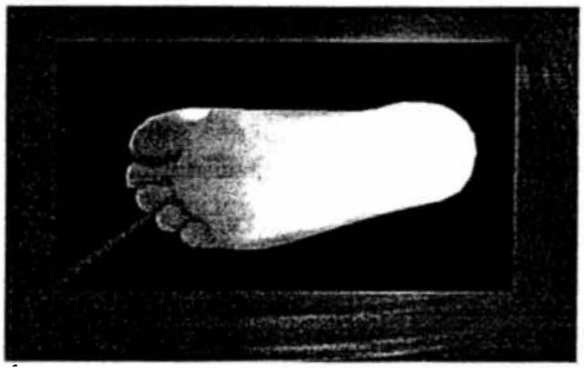

Figure III-10. Repaired Bottom View

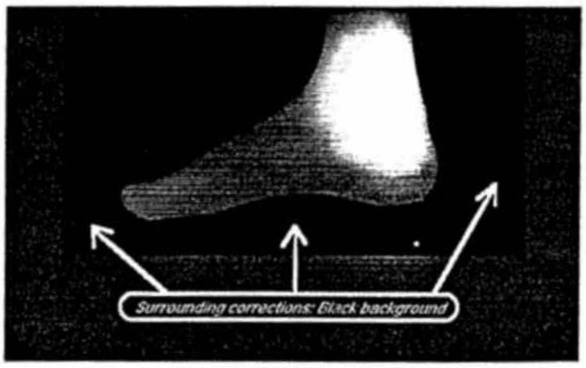

Figure III-11. Repaired Side View

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Then load the image using *Open* and *File*. There are two consecutive files belonging to the same foot: the two file names must be equal except the last digit in the file name extension. If anyone of such two paired files is missing or could not be successfully repaired, than both files will be omitted. Decide whether there are any errors (reflections, mirror lights etc.), and if yes start the correction procedure by setting up the pen color and fill color to black. Using the *filled polygon tool* to draw round the foot's contour the unnecessary objects could be eliminated. Finally *Save* the modified picture to the same name.

3.2.2. Graphic Image Processing Program

Images created by the FootGrab program are digitized "photos" taken from the respondents' feet from two (bottom and side) views. The target is to produce the given sizes of feet in standard numeric form – because of the large amount of data - ordered into databases. The system realizing this target is the program FootProc.

Concept of FootProc: Principles of Converting

FootGrab program creates image files in 640x400 pixel resolution, within 256 gray scales. The first task is to convert this image into a monochrome (2 color) bitmap. This requires a brightness threshold value, to be chosen by the user (according to the brightness of the currently processed image). The contour sharpness of feet and the presence of other disturbing light sources depends on this value. Therefore, the first factor which defines the quality of the whole converting process is this *brightness threshold.* An incorrectly selected value can introduce errors, which cannot be corrected during the following steps.

Now we have a monochromatic bitmap including the print of the feet, and other disturbing spots that came from outer lights, or from misplacing of light sources. These spots don't disturb the analyzing process until they are separated from the main object (the print of the measured feet) – they can easily dropped off later.

The next step is to find each object on the monochrome bitmap. FootProc scans through the entire bitmap from top to bottom, left to right direction. After various sorting and collecting processes the bit-mapped image appears as a vectorized data stream which describes the contour of all objects on the sample. The next step is selecting one object (representing the contour of feet), which will be handled as main object - in other words: to suppress all other disturbing objects that has not been filtered within the preceding steps. All following measuring procedure operates on this (main) object only.

There are other kind of errors, that cannot be filtered during the preceding phases. These errors come from placing improperly the measured foot into the Measuring Box (it is rotated in a certain angle). Thus in the next step is possible to rotate bottom- and the side views of foot into the correct direction.

Before measuring each view, all measuring points have to placed onto the side- and bottom view contour. The program tries to place them into they default locations, but the measuring points can be moved on the contour using the mouse. After placing all points the software calculates the described parameters (distances, angles and factors), and writes them into a dBase compatible database file for the statistical operations.

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Screen Template

The steps of analyzing and converting procedure can be stepped forwards and backwards – this method makes possible to apply the trial-and-error technique for inexperienced users.

FootProc is featured with full graphic control. Necessary parameters can be changed using the mouse, but keyboard also can be used (for experienced users) to achieve higher performance when processing big amount of samples. The result corresponding to the current phase is displayed in the *client area* (the upper part of the screen). The lower-right part displays information about the currently processed file/directory, while an help line can be seen in the bottom line of the screen - this displays one-line information on the current process/context. The control buttons are located on the lower-left corner of the screen.

The Control Buttons

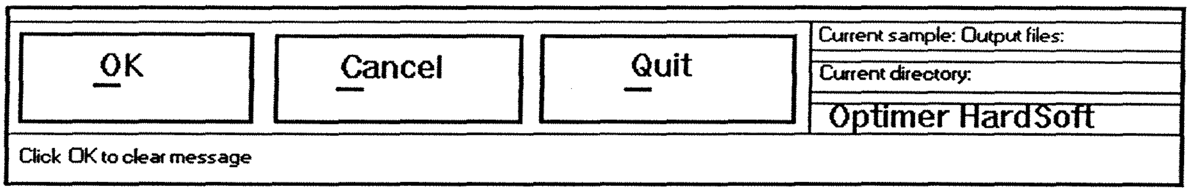

Figure III-12. Buttons for sequential operation

There are four control buttons that remaining on the screen: *OK, CANCEL, BACK* and *QUIT*. Button *CANCEL* is used to delete the last operation, while *BACK* returns to the previous phase of procedure.

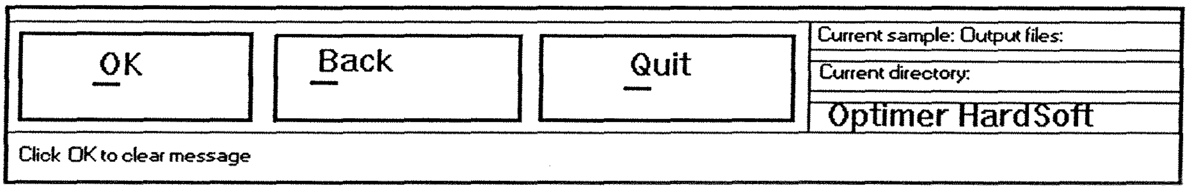

Figure III-13. Buttons for back step operations

3.2.3. Using of FootProc: Processing of a Sample

Using of FootProc is a systematic application of a predefined and preprogrammed series of graphic transformation procedures with the very convenient possibility of back stepping, checking and repeating transformation phases according to the actual results. All manipulations have to be performed for bottom and for side views as well. In case of a pair of ideal pictures without photographic errors, the program provides the automatic procedure, when operator will use only RETURN or OK buttons. Although in usual cases the image parameters are not optimal, thus some manual and semi-automatic solutions will be applied. The samples captured in the same session are creating a series of files. The files follow each other automatically.

The procedure begins with entering the starting file-name. This file-name later will be atomically increased supporting the file-name conventions used earlier by program FootGrab. Then a numeric factor is questioned. This factor will be used for final corrections of numeric sizes retrieved from this procedure. This factor should be interpreted as a calibration factor calculated from comparisons of manual and FMU measurements of etalon samples. Finally we have to specify the name of database assigned to collect the calculated numeric values of samples belonging to the same series.

After entering (or accepting default values) of above data, the gray-scale bit-map image of bottom view will be displayed (see *Figure III-13*).

FIRST STEP: Image Conversion: Bottom View

The first step in the image processing method is to convert 256 gray-scaled digitized image into a monochrome bitmap. For the converting it is necessary to choose a *brightness threshold* value. *FOOTPROC* first shows image in the original color depth (*Figure III-14*). Within this screen, the threshold can be chosen using the "+" and "-" keys on the numeric keyboard. Each pressing of "+" key increases, pressing "-" decreases this threshold value, and the resulting image (imitating the converted monochrome bitmap) will be displayed. (*Note:* the image on this screen will be displayed in half resolution than the original image.) The "**ENTER**" key continues with the next step. It is possible to omit the currently processed sample with pressing the "**ESC**" key.

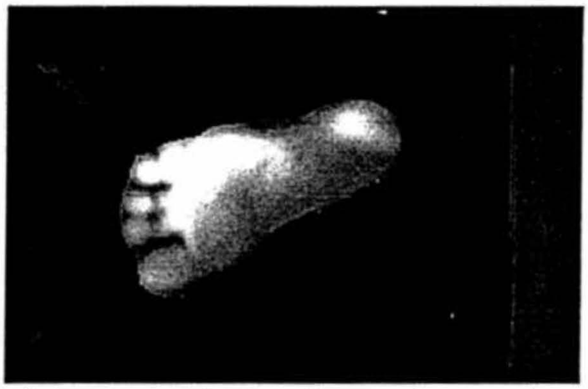

Figure III-13. Gray-scale Image Bottom View

Figure III-14. Starting B/W Image of Bottom View

You should change threshold value until main object stands separated from the disturbing objects. The target is not to *eliminate* these other objects – they can be excluded within the following steps – because an extremely chosen threshold leads to distortion of the main object. If the main object cannot be freed from disturbing objects (or at the expense of large amount of distortion only), the sample should be **excluded** using the "**ESC**" key. (See different stages of B/W conversion on *Figures III-15, III-16* and *III-17*).

Figure III-15.

Figure III-16.

Figure III-16. B/W Conversion

SECOND STEP: Dropping Off Disturbing Objects on Bottom View

Within this phase you are able to select a rectangular area from the whole image. This is useful if the image contains objects, which are in connection with the print of the foot(this is typical to the *side view* images, where on the bottom half of the foot mirroring appears). Otherwise it is not necessary to use this feature, because in the next phase the main object can be simpler (and in most cases automatically) separated.

After finishing manipulations, you should click **C**ONTINUE button (or alternatively pressing either the "**ENTER**" or "**C**" key). This initiates the scanning procedure to find each object on the image.

You are able to return to the previous screen (to modify the threshold value if required) either by clicking BACK button using mouse or pressing the "**B**" key.

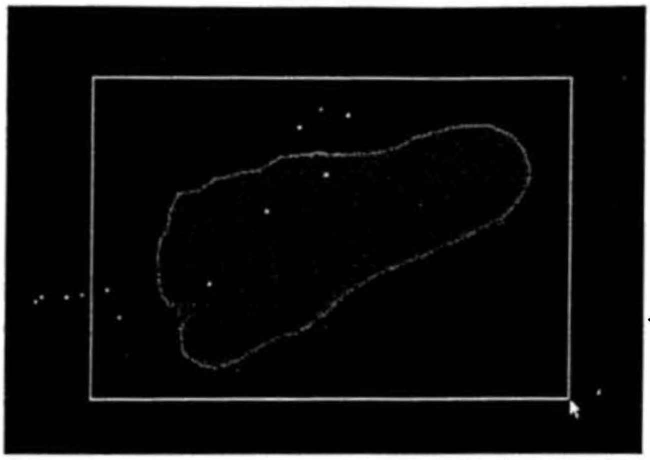

Figure III-18. Main Object Selection.

THIRD STEP: Selecting Main Object on Bottom View

After all objects on the image are scanned, and stored separately in the object database, the main object - on which the measuring process will be performed - must be selected. This operation (in most cases) can be done automatically, since under normal conditions this object has the largest surface. When entering this screen FootProc highlights the object with the largest surface. If it is necessary to select another object, this can be done by clicking the proper object with the mouse. To leave this screen click either CONTINUE button or press the "**ENTER**" or "**C**" key.

Figure III-19. Selected main object

FOURTH STEP: Checking Object Contour

To get correct and exact results within the measurement, it is very important, the contour describing the main object to be clear and be free from any enclosed part object. This fact depends on various conditions, that can be changed within the preceding phases of image processing. Therefore, after the main object has been selected during the previous step, FootProc displays the resulting contour for verifying purposes. If the contour is not 100% free from errors listed below, you must re-execute the preceding steps, make the necessary corrections, and when returned to this screen, newly inspect the contour. If processing parameters within the preceding steps cannot be modified so, that contour shape to be correct, the sample **must be** excluded within the first phase.

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Note: **do not** continue with the measuring process (see following sections) until contour doesn't seem to be correct (see *Figure III-20*), it produces false resulting values in the output database file.

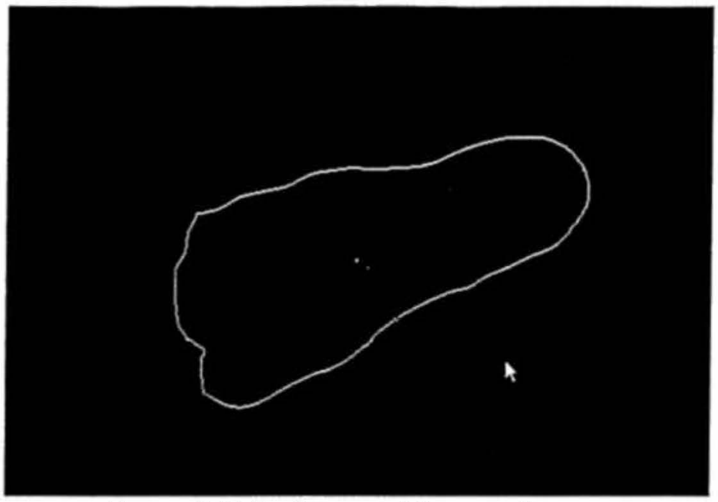

Figure III-20. Generated Bottom Contour

FIFTH STEP: Correcting the Angle of Bottom View

This phase offers the possibility to correct the problem, that occurs, when a respondent's feet were placed the wrong angle/direction into the measuring box. This operation is only important for the proper placement of the horizontal measurement axis.

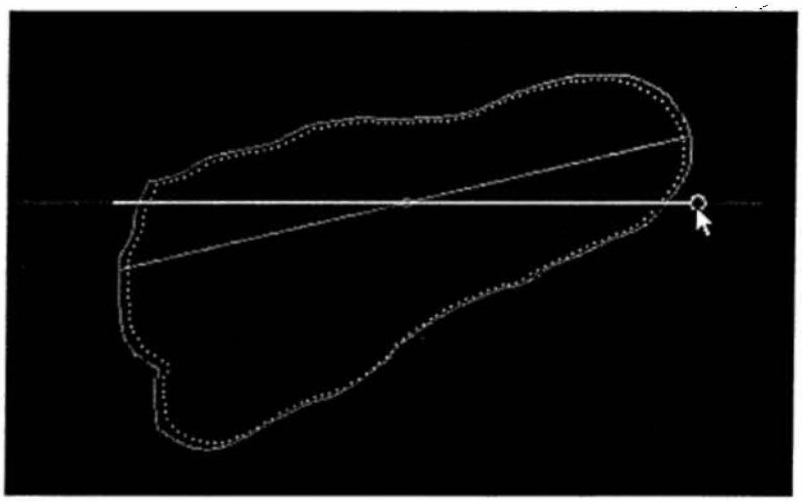

Figure III-21. Rotating Bottom view

SIXTH STEP: Placing the Horizontal Axis of Bottom View

The measuring phase requires a horizontal and a vertical axis from which all measurement originates. The position of the vertical axis can be selected automatically, since it is placed onto the most right point of the foot. Horizontal axis must be placed manually, this can be done within this step.

On the screen appears the bottom view of foot, the vertical axis displayed with red, and the horizontal axis displayed with white color. On the most left point of horizontal axis there is a small circle, this acts as a handler. Moving of horizontal axis is possible as follows;

- click handler on left side of the horizontal axis;
- while holding down mouse button drag axis to its proper position by moving mouse;
- release mouse button.

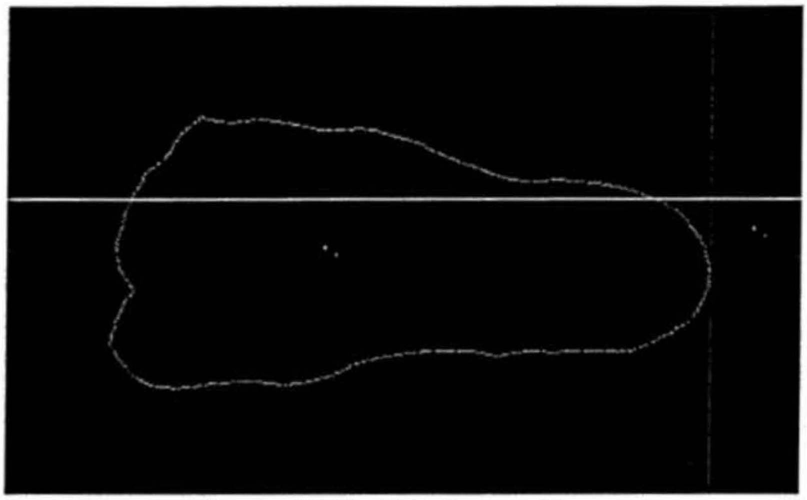

Figure III-22. Shift Bottom View

SEVENTH STEP: Arranging measuring points of Bottom View

This step performs the final preparation of bottom contour for automatic measurements. (It is important to *remember*: it is supposed to have images from the right foot, thus "inner" means left and "outer" means right when applying these phrases to bottom view.) There are nine characteristic points along the bottom contour which have to be assigned according to following conventions:

A1 = inner heel point,
A2 = outer heel point,
A3 = outer shank point,
A4 = outer ball point,
A5 = inner ball point,
A6 = outer small toe point,
A7 = inner big toe point,
A8 = small toe edge point,
A9 = big toe edge point.
(See also *Annex A.*)

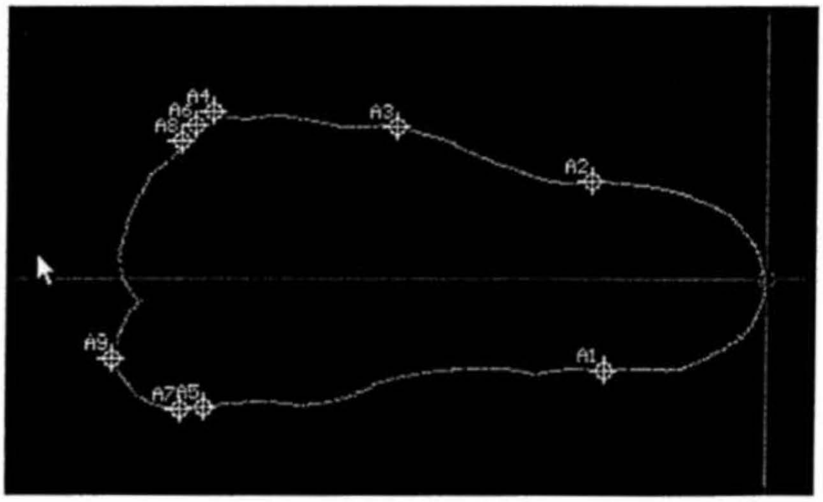

Figure III-23. Wrong configuration of measuring Points

The measurements will be performed using the coordinates of these points, therefore the proper positioning of those are very important.

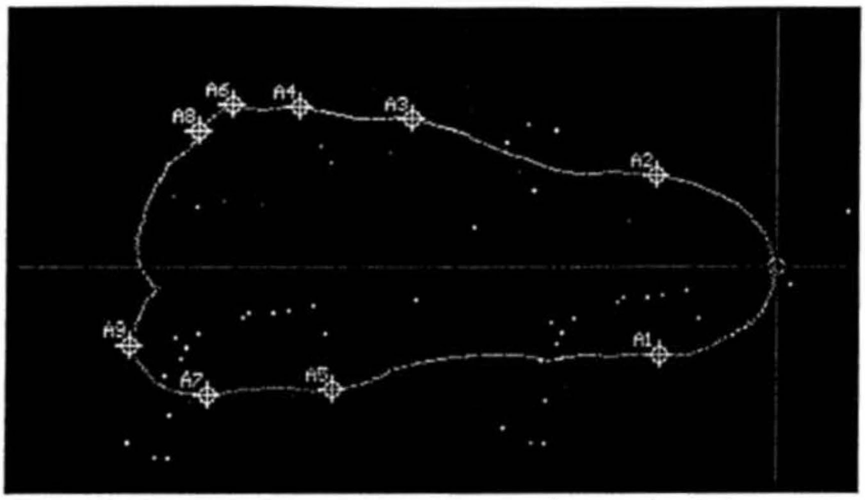

Figure III-24. Proper Arrangement of Measuring Points

The program examines the bottom contour end tries to produce an automatic arrangement (*Figure III-23*). This automatic configuration could be accepted only if all pointsare located in their proper geometric sequence (see *Annex A*) and their geometric location also fits to the appropriate characteristic foot-point detailed above. If something fails it is possible to repair the configuration by moving the point along the contour to the proper place:

- move the mouse cursor to the point to be modified and "pick it up";
- relocate the point by pressing continuously the mouse button;
- release the mouse button.

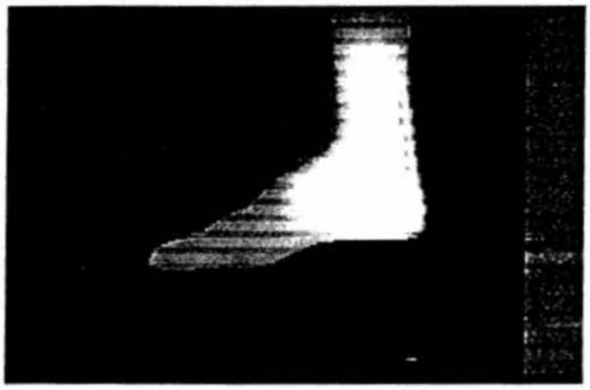

Figure III-25. Gray-scale Image Side View

Figure III-26. Starting B/W Image of Side View

EIGHTH STEP: Image Converting of Side View

In the following steps we have to repeat the operations performedearlier in case of bottom view. The first step here also to convert the 256 gray-scaled digitizedimage into a monochrome bitmap. It is necessary to choose a *brightness threshold* value. FootProc at first will show the image in original color depth (*Figure III-25*). Use "+" and "-" keys on the numeric keyboard to change the threshold setting. Each pressing of "+" key increases, pressing "-" decreases this threshold value, and the resulting image (imitating the converted monochrome bitmap) will be displayed. The "**ENTER**" key continues with the next step. It is also possible to omit the currently processed sample with pressing the "**ESC**" key.

The first keystroke of "+" or "-" will result the display of B/W side view with default threshold (*Figure III-26*). We should change this threshold value until main object stands separated from the disturbing objects. (See different stages of B/W conversion on *Figures III-27, III-28*, and *III-29*.)

Figure III-27

Figure III-28

Figure III-29. Different threshold values

NINTH STEP: Dropping Off Disturbing Objects on Side View

Here we have to disclose the unnecessary objects from Side View. The objects to be investigated should be bordered with a rectangle using mouse. Anything out of this border will be omitted.

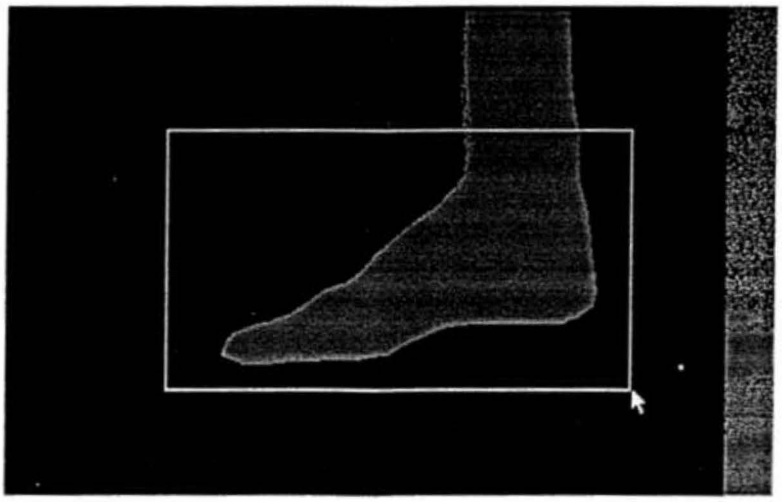

Figure III-30. Main Object Selection on Side View.

After finishing manipulations, you should click **C**ONTINUE button (or alternatively pressing either the "**ENTER**" or "**C**" key). This initiates the scanning procedure to find each object on the image

You are able to return to the previous screen (to modify the threshold value if required) either by clicking **B**ACK button using mouse or pressing the "**B**" key.

TENTH STEP: Selecting Main Object on Side View

After all objects on the image of side view were scanned, and stored separately in an "object database", the main object – on which the measuring process will be performed – must be selected. This operation (in most cases) can be done automatically, since under normal conditions this object has the largest surface. When entering this screen FootProc highlights the object with the largest surface. If it is necessary to select another object, this can be done by clicking the proper object with the mouse. To leave this screen click either CONTINUE button or press the "**ENTER**" or "**C**" key (*Figure III-31*).

Figure III-31. Selected main object

ELEVENTH STEP: Generating Object Contour

To get correct and exact results within the measurement, it is very important, the contour describing the main object to be clear and be free from any enclosed part object. This fact depends on various conditions, that can be changed within the preceding phases of image processing. Therefore, after the main object has been selected during the previous step, FootProc displays the resulting contour for verifying purposes. If the contour is not 100% free from errors listed below, you must re-execute the preceding steps, make the necessary corrections, and when returned to this screen, newly inspect the contour. If processing parameters within the preceding steps cannot be modified so, that contour shape to be correct, the sample must be excluded within the first phase.

Note: **do not** continue with the measuring process (see following sections) untilcontour doesn't seem to be correct, it produces false resulting values in the output database file.

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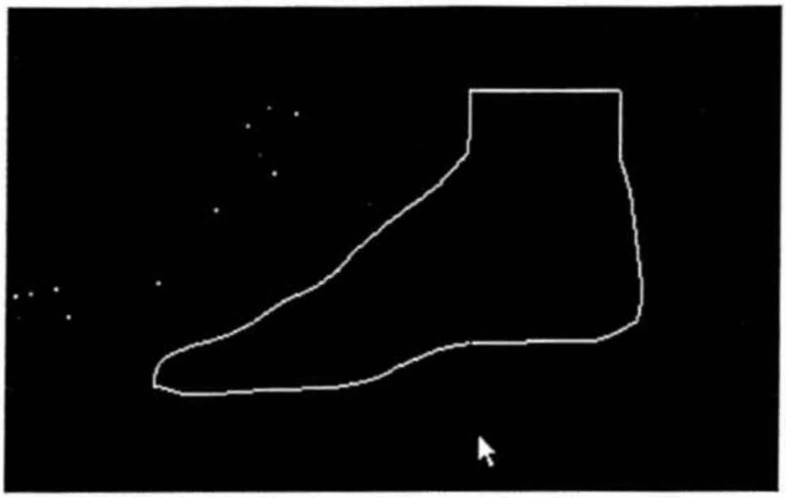

Figure III-32. Generated side view contour

TWELFTH STEP: Correcting the Angle of Side View

This phase offers the possibility to correct the geometric problems in case of wrong positioning of foot in meaning of angle or direction. This operation is also important for the proper displacement of the vertical (Height=z) measurement axis.

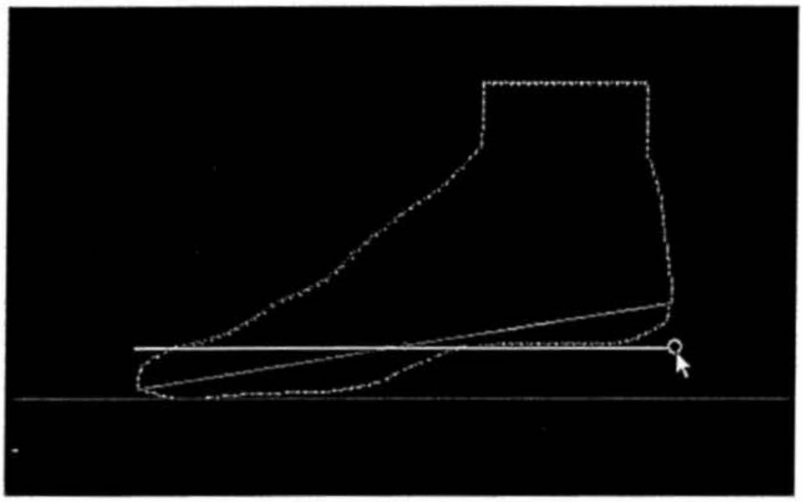

Figure III-33. Rotating Side view

THIRTEENTH STEP: Placing the Horizontal Axis of Side View

The measuring phase requires a horizontal and a vertical axis from which all measurement values will be originated. The horizontal position of the vertical axis will be selected automatically, since it is placed onto the rightmost point of the foot. The vertical position horizontal axis must be placed manually within this step.

When appears the side view of foot, the vertical axis displayed with red, the horizontal axis displayed with white color. On the leftmost point of horizontal axis there is a small knob, this acts as a handler. Move the horizontal as required:

– click handler on left side of the horizontal axis;
– while holding down mouse button drag axis to its proper position;
– release mouse button.

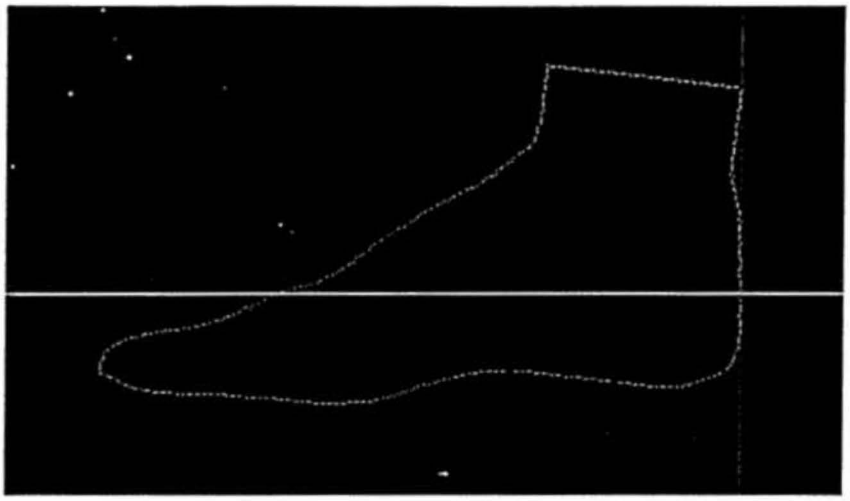

Figure III-34. Shift Side View

FOURTEENTH STEP: Arranging measuring points of Side View

This step performs the final preparation of side contour for automatic measurements. There are ten characteristic points along the side contour which have to be assigned according to following conventions:

P1 = heel back-point,
P2 = heel curve-point,
P3 = heel bottom-point,
P4 = upper instep-point,
P5 = ankle curve-point,
P6 = upper waist-point,
P7 = lower waist-point,
P8 = upper ball-point,
P9 = lower ball-point.
P10 = upper big toe-point.
(See *Appendix A*.)

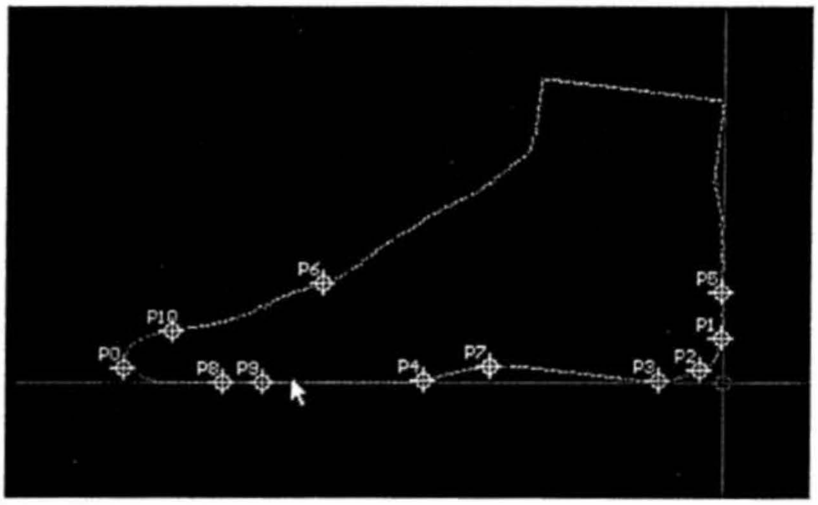

Figure III-35. Wrong configuration of measuring points

The measurements will be performed using the coordinates of these points, therefore the proper positioning of those are very important. The program will analyze the side contour end tries to produce an automatic arrangement (*Figure III-35*). This automatic configuration could be accepted only if all points are located in their proper geometric sequence (see *Appendix A*) and their geometric location also fits to the appropriate characteristic foot-point detailed above. If something fails it is possible to repair the configuration by moving the point along the contour to the proper place:

- move the mouse cursor to the point to be modified and "pick it up",
- relocate the point by pressing continuously the mouse button,
- release the mouse button.

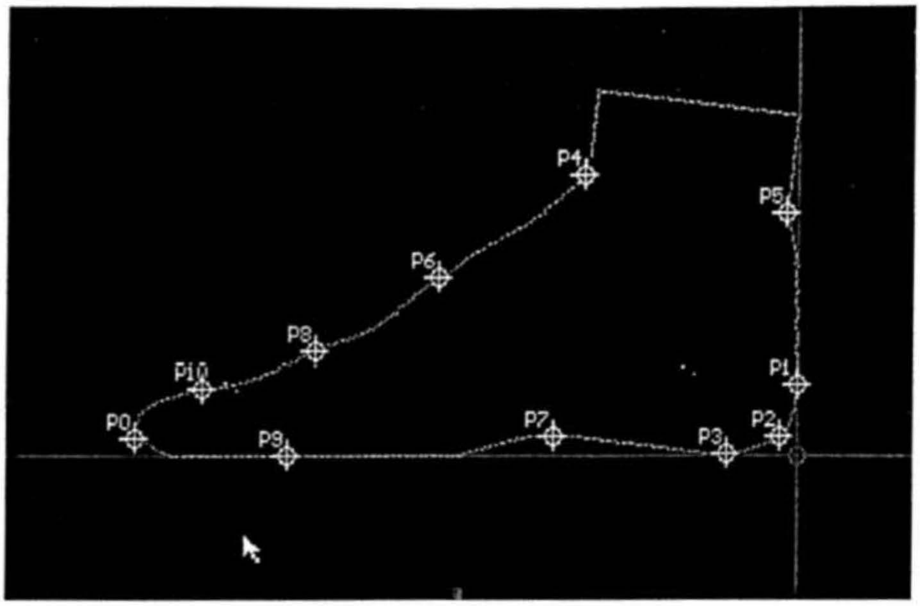

Figure III-36. Proper Arrangement of Measuring Points

The Automatic Measurement

The fifteenth step is the measurement itself. During earlier phases the program generated the two contours, and nine points to the bottom view (A1, ..., A9) and ten points to the side view (P1, ..., P10) were positioned. These points have their own graphic (geometric coordinates) in three dimensions (*x, y, z*). It is possible to calculate the distances between two points, to calculate additional coordinate values, angles, lengths etc. using these geometric data. Thus the automatic measurement procedure is a set of mathematical calculations using the coordinates of characteristic points of foot. Calculations also include the application of transformation factor entered on one of opening screen of FootProc. This factor transforms the screen coordinates to millimeter coordinates. *Remember:* this factor's value is a result of calibration measurement to be performed after each new installation of FMU.

Program FootProc performs automatically all the calculations described in *Annex B*. In case of each unique measurement the calculation results are collected into one data-record which is written into the selected database (their structure are given in *Annex C*).

For exact interpretation of variables represented by different FIELD_NAMES see *Annex C*. Each variable has its own geometric and mathematical meaning, and all values are stored as millimeters The precision of calculations preserves the precision of images i.e. should be under one millimeter.

The flowchart of FootProc is shown on *Figure III-37* (see next page).

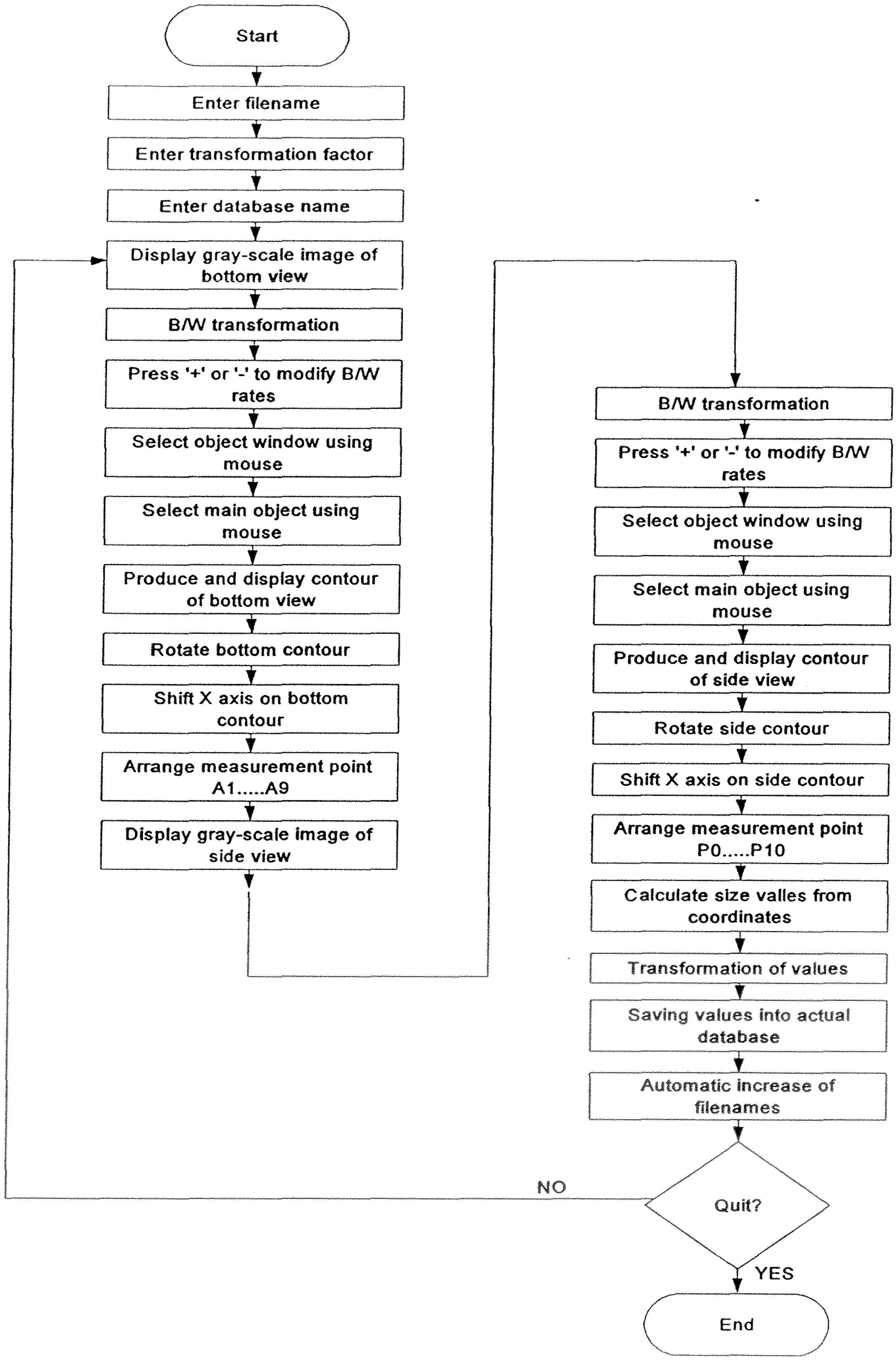

Figure III-37. Flowchchart of FootProc

3.2.4. Graphic and Numeric Data Elaboration Procedure

The so called numeric data collected by manual entering intoFootDat program (see paragraph 3.1) were stored in different kind of databases. As it was described in paragraph 3.2 the so called graphic data, i.e. the data with graphic origin from FootGrab and FootProc were collected also into databases. The two groups of data are chained through the CODE field containing the barcode identifying the investigated persons. In the following phase of survey we have to handle these two groups of data together. To realize this unity there are two procedures necessary to proceed: rough filtering and structural joining.

Filtering and Sorting

The measurement procedure should produce many kinds of troubles which will appear in the contents and in the form of retrieved data. The causes of errors are very different. E.g. the measurement could be successful but the data stored on hard drives or digital tapes are not readable again, or the measurement was done but the resulted picture's quality is not compatible with the system, etc. The typical main errors are the following:

Missing Numeric Data Field
Could appear in case of numeric data only, e.g. operator forgot to measure or to enter some data. If optional data fields are missing the record remain valuable. In case of missing main data field we have to omit the record.

Missing Graphic Data Field
Could appear in case of graphic data only, when one of the views of bottom or side view was an absolute wrong picture but the operator forgot to omit i.e. to 'step over' the record by pressing "**Esc**". In this case the strange or incomplete results produced by automatic calculations will be omitted.

Missing Numeric Data Record Pair
This is the case when the graphic data belonging to a given CODE exists, but the appropriate numeric data record is missing. The graphic data record have to be omitted.

Missing Graphic Data Record Pair
This is the case when the numeric data belonging to a given CODE exists, but the appropriate graphic data record is missing or wrong. The numeric data record have to be omitted.

Redundant Data Record Pair
This case could occur when the same barcode identifier were applied morethen one time during the same survey: there are two or more numeric or graphic data records belonging to the same CODE value. The records must be studied and the best data record pair will be selected, the others will be omitted.

The procedure filtering the records belonging to any of above errors have be performed in a database program environment. Using e.g. dBase, FoxPro or Clipper these databases are indexed on the field CODE establishing a direct relationship between them. The following step is tha data comparison and elimination of errors. (The number of images processed in the foot survey in India was 7947. The number of record-pairs resulted by this first filtering procedure was only 3783.)

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Merging Graphic and Numeric Data

After the filtering procedure the data of two groups are ready to join. After having indexed both databases by ascending CODE field they are merged. The result database will contain all the data necessary to start the statistical investigations.

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Chapter IV

STATISTICAL DATA ANALYSIS

The basis of statistical process is the merged (unified) database retrieved from numerical data collection and from calculations based on graphic images. The origin of this database were the data filescollected by staff of CLRI from different regions of India. The amount of collected data were as indicated below.

Amounts of *numerical data* collected by manual recording during the measurements:

Number of DATA1 records from Southern region	2443
Number of DATA2 records from Southern region	2430
Number of DATA3 records from Southern region	16
Number of DATA1 records from Northern region	2439
Number of DATA2 records from Northern region	2441
Number of DATA3 records from Northern region	112
Number of DATA1 records from Western region	1631
Number of DATA2 records from Western region	1545
Number of DATA3 records from Western region	113
Total number of DATA1 records from all regions	6513
Total number of DATA2 records from all regions	6416
Total number of DATA3 records from all regions	241

Similar amount of data were available from Eastern region, but without graphic data these result are unusable. The above listed data were stored in un-compressed database format on floppy discs. All the discs were checked and those are all readable and ready to use. Of course only those data records could be involved into later analysis which have their correct pair among graphic data. The graphic imagepairs were stored on digital cartridges. Two type of cartridges were used: 250 Mbyte capacity with QIC-80 format and 120 Mbyte capacity with QIC-40 format. On QIC-80 tapes the maximum number of image pairs was 100, while in case of QIC-40 tapes the maximum was 50 pairs.

Amount of *graphic data* collected by automatic grabbing during the measurements:

Number of cartridges from Southern region	15
Number of readable cartridges from Southern region	14
Number of cartridges from Northern region	12
Number of readable cartridges from Northern region	9
Number of cartridges from Western region	5
Number of readable cartridges from Western region	1
Number of cartridges from Eastern region	11
Number of readable cartridges from Eastern region	0
Total number of cartridges collected from all regions	43
Total number of readable cartridges collected from all regions	24
Number of persons covered by data of readable cartridges	4396
Number of persons covered by data of processed image-pairs	3783

These numbers reflect to the starting(initially available) amount of data. This amount was decreased later, when the merged (main) database was created an filtered

4.1. Description of the Main Database

The geometric interpretations of numeric data areexplained in *Annex A*, while their detailed (verbal or mathematic) explanation together with description of personal data are available in *Annex B*.

4.2. Basic Statistical Investigations

The first statistical task was to study the whole data as a so called statistical population and determine the direction of possible detailed analysis. There were three main viewpoints of this first study:

a) *distribution by sexes:* the children's feet have the same characteristics independently from their sex up to a specific age - the task is to determine that age from which the basic parameters are definitely different for boys and girls;

b) *distribution by ages:* the human foot is growing together with the body up to a specific age only - the task is to determine the ages for both sex from which the basic parameters remain definitely unchanged;

c) *distribution by regions:* the population of different regions could represent different anthropometric characters - the task is to determine whether it is necessary to elaborate different foot industrial standards for specific regions or not.

Using any commercially available statistical program packages (e.g. StatGraphic, Stat, SimStat) or database management programs (dBase, FoxPro, Clipper) or spreadsheet (e.g. Lotus-123, Excel, QuattroPro) the following parameters can be calculated and studied for the populations:

- number of valid cases
- mean
- minimum
- maximum
- standard deviation

These statistical parameters were first calculated for each variable in the database (for filtering purposes), later the number of variables were decreased to the most important ones, namely:

- HEI Height
- WEI Weight
- L1 Orthogonal Length
- L2 Oblique Length
- W1 Heelprint Width
- W2 Outer shank Width

The following table lists the frequency distribution of original data by ages:

Age	*Cases*	*Age*	*Cases*	*Age*	*Cases*	*Age*	*Cases*	*Age*	*Cases*
3	78	13	337	24	15	35	30	46	14
4	77	14	266	25	30	36	14	47	11
5	144	15	120	26	28	37	14	48	9
6	194	16	157	27	17	38	18	49	6
7	152	17	9	28	21	39	8	50	5
8	186	18	20	29	19	40	20	51	7
9	213	19	38	30	24	41	7	52	5
10	250	20	24	31	43	42	10	53	4
11	246	21	29	32	40	43	13	54	7
12	275	22	20	33	29	44	15	55	3
		23	23	34	17	45	18		

Table IV-1 shows the population distribution by sex and by age with averages of orthogonal length(*L1*) and heel width (*W1*).

Table IV-1

Average foot lengths and ball widths

Age	Sex			
	Female		Male	
	L1	*W1*	*L1*	*W1*
3	164.42	48.89	170.05	51.92
4	178.02	51.37	179.35	52.06
5	191.66	54.13	190.49	54.41
6	194.45	53.79	195.97	56.83
7	199.84	54.69	202.80	55.66
8	211.99	57.47	212.25	60.22
9	217.78	57.94	218.29	60.06
10	224.61	59.87	226.43	61.45
11	230.73	61.32	235.28	63.33
12	239.74	61.97	241.77	64.04
13	241.69	64.50	245.67	66.37
14	236.36	64.11	249.17	66.94
15	234.24	63.21	252.20	68.44
16	225.62	62.12	249.69	70.18
17	240.41	69.00	267.70	71.30
18	246.50	65.00	272.23	70.84
19	244.51	66.77	271.10	69.91
20	242.81	68.02	268.99	71.10
21	248.60	67.14	264.78	71.61
22	238.81	67.10	263.97	70.47
23	255.28	68.22	265.41	69.91
24	-	-	259.61	69.12
25	240.70	62.19	261.28	69.73
26	247.23	66.47	260.66	71.86
27	234.90	68.69	262.19	71.91
28	236.62	62.74	258.77	69.83
29	237.80	68.15	255.37	70.39
30	254.00	73.90	262.55	70.90

Age	Sex			
	Female		Male	
	L1	*W1*	*L1*	*W1*
31	237.92	67.94	262.30	70.78
32	243.59	67.86	260.12	70.05
33	238.96	69.67	264.40	70.20
34	236.91	66.61	262.38	71.06
35	241.39	69.66	262.97	71.45
36	240.24	63.24	263.13	70.30
37	245.63	70.08	267.31	71.16
38	233.58	71.69	263.07	74.63
39	236.34	66.11	250.35	72.53
40	242.88	67.83	262.72	72.86
41	251.72	60.20	261.94	74.01
42	231.37	62.83	259.19	75.09
43	251.72	67.50	263.25	79.78
44	224.67	67.33	263.68	72.90
45	247.45	70.73	260.71	73.19
46	234.82	73.57	258.09	71.99
47	236.64	64.67	266.27	72.88
48	-	-	254.79	73.58
49	256.93	71.07	266.08	76.57
50	245.05	61.12	273.37	75.32
51	-	-	259.49	72.65
52	245.52	64.88	272.31	76.20
53	-	-	250.84	74.19
54	-	-	269.60	77.01
55	-	-	250.67	72.85

This amount of data basically is enough to initiate a statistical analysis. Investigating the unique variables, their distribution shows a relative good normal or close-to-normal distribution form. The following figures are representing the distribution of variables involved into basic statistical investigations.

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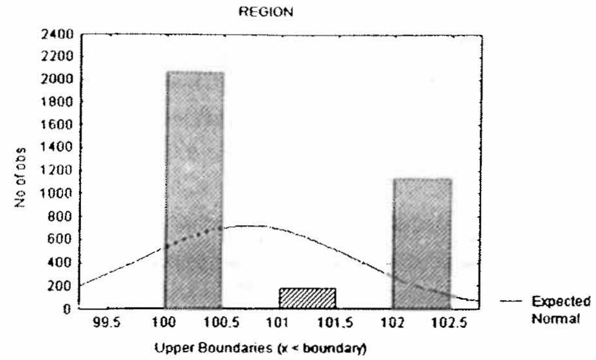

Figure IV-1. Distribution of Regions

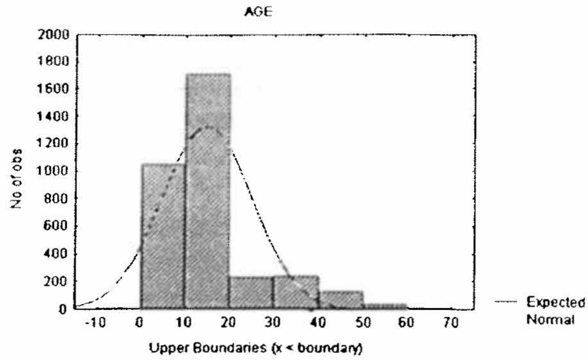

Figure IV-2. Distribution of Ages

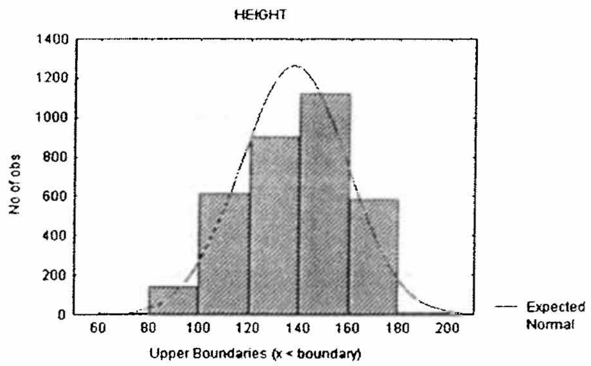

Figure IV-3. Distribution of Height

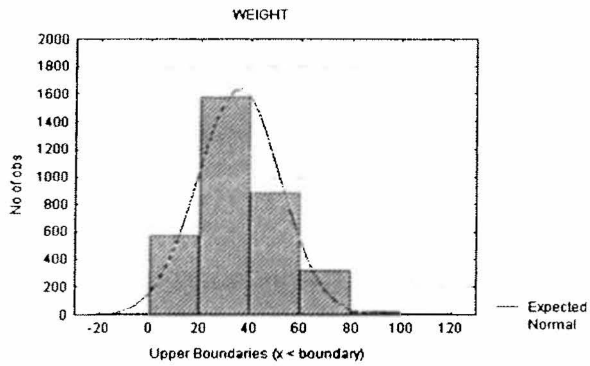

Figure IV-4. Distribution of Weight

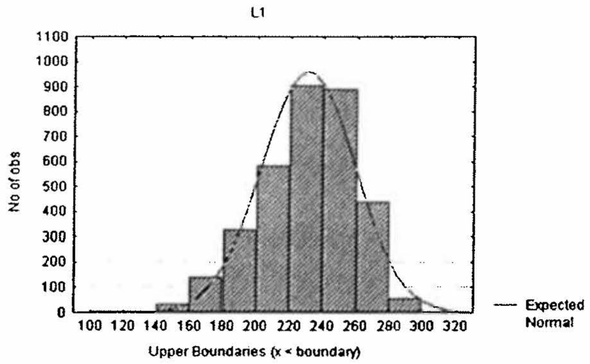

Figure IV-5. Distribution of L1

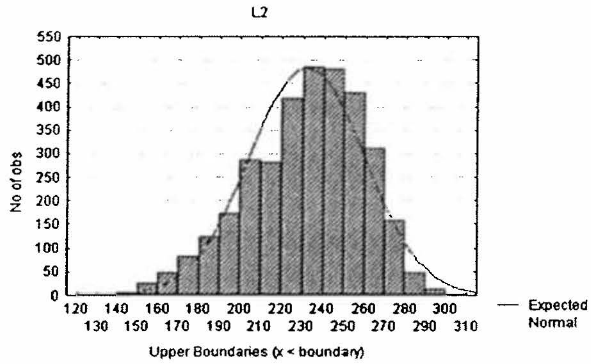

Figure IV-6. Distribution of L2

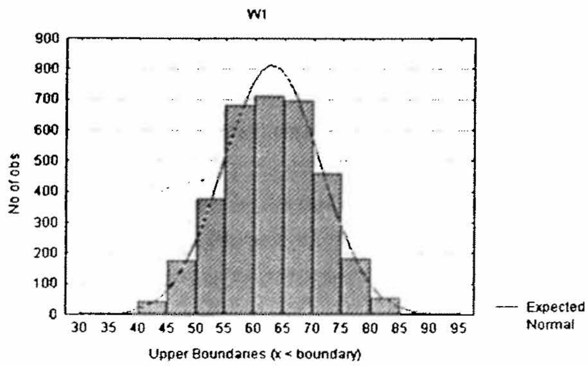

Figure IV-7. Distribution of W1

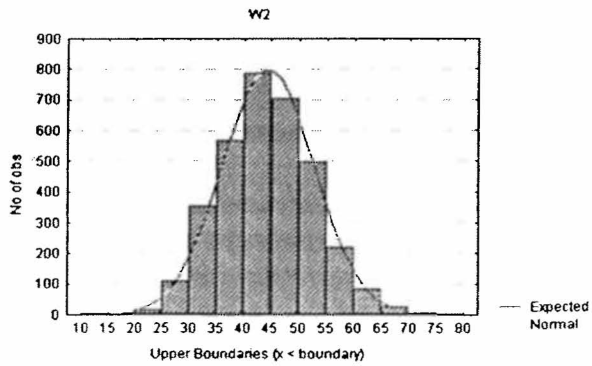

Figure IV-8. Distribution of W2

4.3. Filtering According to Basic Parameters

The basic parameters (*M*=*M*ean and *D*=*D*eviation) could be used as comparison standard for additional filtering the database. In this case the following procedure was applied (X_i is the factual variable):

a) *calculation* of basic parameters for original database,
b) *filtering* with 3*D disclosure rule:
   - if Abs(M_i - X_i) < 3*D_i then the record of variable remained in database,
   - if Abs(M_i - X_i) ≥3*D_i then the record of variable was omitted from database.
c) *calculation* of basic parameters for the new restricted database,
d) repeated filtering with 3*D disclosure rule for the new restricted database:
   - if Abs(M_i - X_i) < 3*D_i then the record of variable remained in database,
   - if Abs(M_i - X_i) ≥3*D_i then the record of variable was omitted from database.
e) *calculation* of basic parameters for the new restricted database,
f) calculation of *Student*'s values (t_i) and checking the normality of the distributions,
g) *additional filtering* if required to reach the satisfactory level of normality.

This filtering procedure performed on the database produced by the foot survey in India reduced the populations to 3502 records.

4.4. Creating Five Data Groups

The next task was to determine the so-called *Sex-Point* (the age from which the parameters of two sex groups are different) and the *Age-Point* (the age from which the parameters of given sex group are unchanged). Being all values normally distributed, the decision condition was : whether the two sex groups or two age groups are belonging to the same distribution or not.

More exactly the procedure was performed in the following steps (*M*=*M*ale, *F*=*F*emale):

- separating AGE groups into smaller databases (files AGE4,...,AGE55), (ages 3 and 4 were merged),
- separating SEX groups for each AGE group into databases (files AGE4M, AGE4F, ..., AGE55M, AGE55F),
- comparing two SEX group distributions of the same AGE. If the probability ofbelonging to the same normal distribution was over 0.95 (95%) for the most important variables, the two SEX groups were declared to belong to the same distribution and the two files were joined again.
- the first AGE where important differences were found between SEX groups was the age 12, thus the *Sex-Point* was set to 11, i.e the records for which **4≤AGE≤11** will be handled AGE by AGE in a *unisex* file: the group of these files was named as *CHILDREN*, containing 8 files for ages 4 to 11,
- the young people are in intensive growing, therefore the two distributions at first are very different, so if the probability of belonging to the same normal distribution became over 0.95 (95%) for the most important variables, then we can announce the end of growing period,
- the first AGE where impressive equalities were found between two consecutive AGE groups were the ages 18/19 in case of both sex, thus the *Age-Point* was set to 18, i.e the records for which **12≤AGE≤18** will be handled AGE by AGE and SEX by SEX in separated files - the two groups of these files were named as *BOYS* for SEX=M and respectively as *GIRLS* for SEX=F (the two groups contain 7 files each),
- the remaining data are belonging to the population which finished its growing, thus the parameters are not belonging from the value of AGE, but only from the value of sex. The

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records with **AGE≥19** and with the same SEX were merged into the same database - these two files of adults are creating the group *MEN* and the group *WOMEN*.

Following the above procedure and statistical criteria applied to the database obtained through the foot survey programme in India five data (size) groups were produced (see also *Figure IV-9*):

1 ■ **C**-GROUP:	children	(boys and girls 4-11 aged)
2 ■ **G**-GROUP:	girls	(only girls 12-18 aged)
3 ■ **B**-GROUP:	boys	(only boys 12-18 aged)
4 ■ **W**-GROUP:	women	(only women 19-55 aged).
5 ■ **M**-GROUP:	men	(only men 19-55 aged)

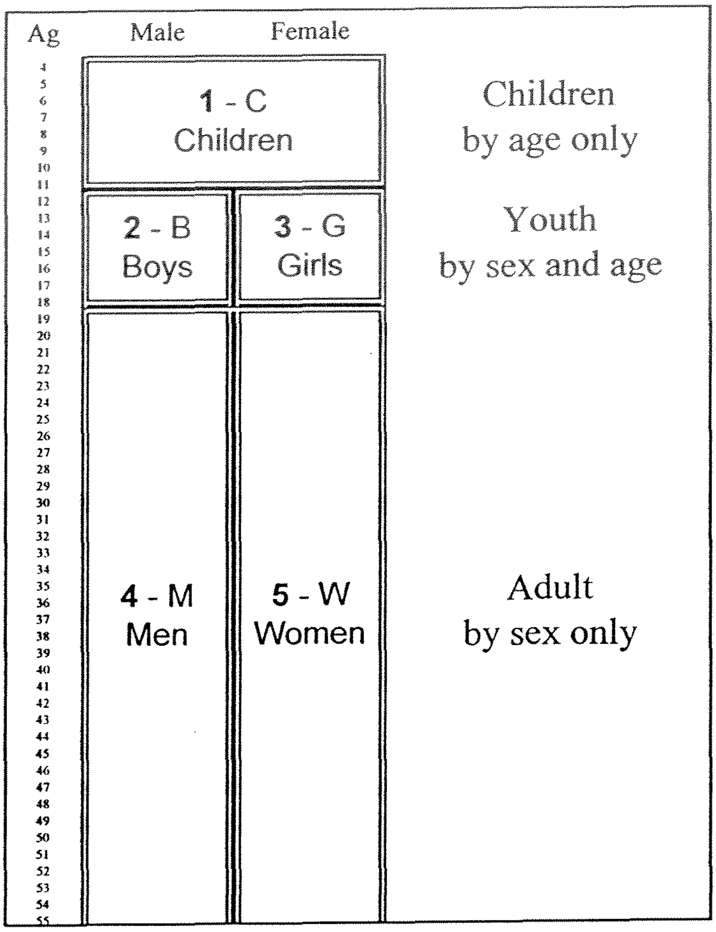

Figure IV-9. Data (size) groups

4.5. Creating Derived Size Variables and Size Databases

These five data-groups were the start-points for the next stages of statistical investigations. It was a declared target to perform all the following analysis steps for English and also for French foot-sizing systems.[15] This task required to introduce new variables.

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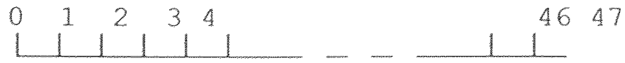
[15] The reasoning used in this chapter is based on arithmetic considerations and serves the mathematical statistical analysis of foot survey data. Another - more footwear technology oriented - explanation of the French and English shoe sizing systems is given in Chapter IV.

4.5.1. The French Point System

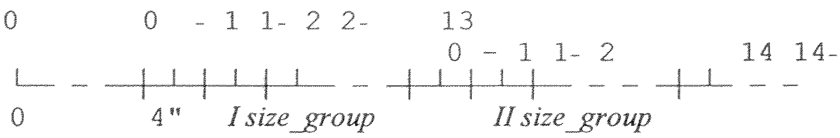


1 French point = 2/3 cm = 0.667 mm, French size (*fr_size*) is the number of French points rounded up to the nearest integer, i.e.

$$fr\_size = \mathrm{Int}(cm\_size * 1.5 + 0.5)$$

where *cm_size* is the foot length in cms. In tables a subset of 2-digit integers are representing one *french_size* are commonly used.

4.5.2. The English Size System



1 English size = 1/3 inch = 0.846 cm, the English-size= is the number of English-units rounded up to the nearest integer, starting only from 4", i.e.

$$en\_size = [(cm\_size - 10.16) * 1.182 + 0.5]$$

where *cm_size* is the foot-length in cms. The first 13 unit create the first size-group and the units starting with 13 create the second size-group.

Half English sizes[16] are also used widely in the footwear industry. One *English ½-unit* may be defined as follows: if residual is more than a half, i.e. [(*cm_size* - 10.16) * 1.182 + 0.5 } > 0.5] then the integer will be upgraded with a ½-unit.

In tables the English size-groups (1 or 2) are represented numerically on the decimal position of 100's, the integer size on the position of 10's and 1's, while the half-sizes are represented on the position of the first decimal fraction digit. E.g. the value 210.5 represents the size 10- =10½ belonging to II size-group; it is equivalent to 30.04 cm=300.4 mm of foot length.

4.5.3. The Procedure of Statistical Investigation on Sizes

The short description of procedure to be performed is the following:

- all the following procedures have to be performed for each five groups mentioned above,
- without making differences by age in the same group, all data are unified into a single statistical data file,
- using measured data and the computation method given above we calculate for each object:
  - the French-size (FR_SIZE),
  - the English-size (EN_SIZE),
- every further process are performed on both (French and English) data,

---

[16] Sometimes half English sizes are marked with a hyphen or minus sign ("-") written after the whole number: e.g. "4-" means 4½. Decimals, e.g. 4.5 are use seldom.

- after sorting the groups by size-numbers, we create a unique table for each size-number (this means one table for each occurred size, i.e. 77 French size-tables and 121 English size-tables),
- for every such table we have to calculate the basic statistical parameters (frequencies, means, deviations),
- then we create one new table for each group (that means 10 tables all together), containing the size-numbers as objects, and above calculated following statistical parameters as variables,

Frequency:	number of occurrence of unique sizes	(FREQ)
Mean of	*HEIGHT* for the given size-number	(M_HEI)
Mean of	*WEIGHT* for the given size-number	(M_WEI)
Mean of	*L1* for the given size-number	(M_L1)
Mean of	*L2* for the given size-number	(M_L2)
Mean of	*W1* for the given size-number	(M_W1)
Mean of	*W2* for the given size-number	(M_W2)
Deviation of	*HEIGHT* for the given size	(M_HEI)
Deviation of	*WEIGHT* for the given size	(M_WEI)
Deviation of	*L1* for the given size-number	(M_L1)
Deviation of	*L2* for the given size-number	(M_L2)
Deviation of	*W1* for the given size-number	(M_W1)
Deviation of	*W2* for the given size-number	(M_W2)

- calculation of correlation coefficients and correlation tables,
- generation of histograms belonging to the FREQ variable in the new tables,
- using the statistical MEANs of these 10 tables we can select the so called middle size values and to calculate the typical geometric data for last modeling.

4.5.4. Size Formulas Used in Statistical Calculations

The database field named *L1* is one of the data descripting the length of the foot in millimeters. Using this field the formulas applied are as follows:

Variable-name/field length	*Formula*
FR_SIZE3/0	TRUNC(L1*1.5/10+1)
EN_NUM6/2	(L1/10-10.16)*1.182
EN_GROUP2/0	((EN_NUM/13)>1)+1
EN_HALF2/0	1+((EN_NUM-TRUNC(EN_NUM))>0.5)
EN_INT5/1	TRUNC(EN_NUM)+EN_HALF*0.5
EN_SIZE6/1	EN_GROUP*100+EN_INT-(EN_GROUP-1)*13

4.5.5. File Names and Their Sizes Used in Statistical Computations

Data-type	*File-name*	*File-size(number of cases)*
Children	SIZ4_11.STA ©	1540
Girls	SIZ1218f.STA **(G)**	547
Boys	SIZ1218m.STA **(B)**	757
Women	SIZ1955f.STA **(W)**	515
Men	SIZ1955m.STA **(M)**	143

4.5.6. File Names Used to Mark Files Belonging to Size Numbers

Data-type	*French-size-file*	*English-size-file*
Children	FCXX.STA	ECXXX-X.STA
Girls	FGXX.STA	EGXXX-X.STA
Boys	FBXX.STA	EBXXX-X.STA
Women	FWXX.STA	EWXXX-X.STA
Men	FMXX.STA	EMXXX-X.STA

4.5.7. Numerical Distribution of Cases in Files of Unique Data

Data-type	*French-size-file*	*English-size-file*
Children	FC : 22 pcs (21 - 42)	EC : 34 pcs (104.5 - 208.0)
Girls	FG : 14 pcs (29 - 45)	EG : 27 pcs (110.5 - 210.5)
Boys	FB : 17 pcs (30 - 46)	EB : 25 pcs (112.0 - 211.0)
Women	FW: 14 pcs (33 - 46)	EW: 21 pcs (201.0 - 211.0)
Men	FM: 10 pcs (33 - 42)	EM: 14 pcs (201.0 - 208.0)

Table IV-2 and *IV-3* shows the frequency distribution of French and English sizes of feet respectively measured in India through the recent foot survey.

Table IV-2

Size frequencies for French-sizes (F_FREQ)

French	Children	Girls	Boys	Women	Men
FR_SIZE	4-11(FC)	1218F(FG)	1218M(FB)	1955F(FW)	1955M(FM)
21	1				
22	3				
23	11				
24	17				
25	33				
26	34				
27	72				
28	83				
29	128	2			
30	115	2	1		
31	188	11	3		
32	144	14	11		
33	170	30	17	1	5
34	182	62	68		5
35	133	90	76	4	13
36	102	85	93	17	32
37	64	112	97	46	41
38	34	69	118	57	25
39	17	39	103	94	13
40	5	22	72	105	7
41	3	8	52	96	1
42	1		30	53	1
43			14	22	
44			1	15	
45		1		4	
46			1	1	

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Table IV-3

Size frequencies for English-sizes (E_FREQ)

Size EN_SIZE	Children 4-11(EC)	Girls 1218F(EG)	Boys 1218M(EB)	Women 1955F(EW)	Men 1955M(EM)
4-	1				
5					
5-	5				
6	7				
6-	9				
7	15				
7-	18				
8	26				
8-	21				
9	47				
9-	45				
10	60				
10-	65	1			
11	74	1			
11-	84	2			
12	110	6	1		
12-	104	6	5		
13=0	97	11	6		
0-	111	13	11		
1	100	19	9	1	5
1-	122	43	33		5
2	87	44	52		
2-	93	57	54	3	12
3	72	56	54	7	11
3-	52	55	56	18	28
4	50	81	68	26	27
4-	23	41	68	35	20
5	19	44	80	41	13
5-	13	30	72	61	11
6	3	16	50	69	5
6-	3	12	40	63	4
7	3	8	37	58	1
7-			27	53	
8	1		17	36	
8-			9	14	
9			7	14	
9-				9	
10				4	
10-		1		2	
11			1	1	

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Chapter V

ELABORATION OF SIZE RANGES

The ultimate objective of the foot measurement survey is to identify size (length, width/girth) ranges required to cover the need of the local population for footwear, to define proportions and rules of constructing shoe lasts (the inner volume of shoes) providing well fitting and healthy shoes. Based on such data and corresponding documentation shoe lasts for middle sizes of each established groups should designed and tested through fitting trials. Finally guidelines may be prepared for coordinating geometric properties (sizes,contours, shapes) of various types (e.g. functions, toe parts, heel heights) of shoe lasts, as well as for economic coordination of shoe components and respecting moulds/tools used in production.

The flowchart presented on *Figure I-1* (see *Chapter I*) describes the entire process of the scientific foot measurement survey including data processing, mathematical statistical data analysis and preparation of technical documentation for footwear design and technology. The present report has already covered the preparatory phase, the equipment and computer software aspects of the actual measurement process and method, the foot image processing and the creation of basic size groups such as 1-children, 2-boys, 3-girls, 4-men and 5-women (the databases are stored in the respective files named FOOT*n*.DBF where n=1,2,...,5.

5.1. Foot Sizes

For further - especially footwear technology related - analysis of data collected during the foot survey and gained by processing foot images will need to express the main dimension: the foot length in units of measurements used by the most commonly adopted shoe sizing systems such as French points and English sizes.[17] As it is well known a French point is equivalent to 2/3 cm (6.67 mm). The English scale is based on the traditional British measurements of distances, namely an English shoe size[18] unit is 1/3" = 8.46 mm, but the market in consumers societies (industrialized countries) forced manufacturers and trades to supply footwear in half sizes (4.23 mm).[19] The English system is split up into three zones: the initial length is 4" = 12 sizes (101.6 mm), the first (I or children) group ranges from 0 to 13 sizes (in fact from 4" to 8 1/3" or from 12 to 25 English size units or in SI metric terms from 101,6 mm to 207.4 mm), the second (II or adult) group starting at 8 1/3" or 25 English sizes or 207.4 mm but having no upper limit (see *Figure V-1*).

In order to save computation time during data processing it seemed to be feasible to create a few new fields in the data record consisting individual measurements and personal characteristics. The explanation of these fields is given in *Annex B*.

[17] Since the American shoe size system is rather complicated, far from being coherent and hardly used at all in India (certainly not in domestic trade), it is disregarded by the future analysis. On the other hand due to its logical similarity with the English system and availability of relatively simple (but not exact) ways of relating it to other systems the computation results may be interpreted for the American sizes as well.

[18] The word "size" as shoe measurement unit should carefully be distinguished from the term of the (linear or any other) dimensions.

[19] One foot (1') is equivalent to 12 inches (12"): this shows that the foot length of an "average" man was built in the basic of the British general measurement system. (The "inch" originates from the width of the thumb.)

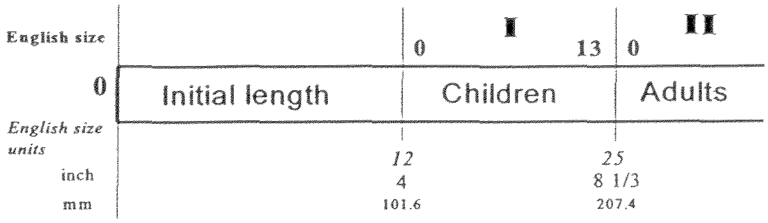

Figure V-1
Structure of the English shoe sizing system

Both French and English (and of course the American) shoe sizing systems express foot sizes *indirectly*, i.e. the size shown on footwear corresponds to the lengths of the shoe last bottom pattern and not to the foot which it fits. In other words the size indicated on footwear and/or its packaging indicate the dimension of the footwear rather than the corresponding foot. When we measure a foot and express its length in any of these units then this size is smaller than the required shoe size. The foot length as defined in this project is shorter by the so called toe-part allowance of the shoe last (*Figure V-2*). This allowance provides room for stretching the foot (it happens in the walking process and when bending the foot), for growth (in case of children and youth footwear). The difference between shoe and foot length also depends on the shape of the forepart of the shoe (last). The toe-part allowance is normally about 5-15 mm which corresponds to 1-2 French points or 1-3 half English sizes.

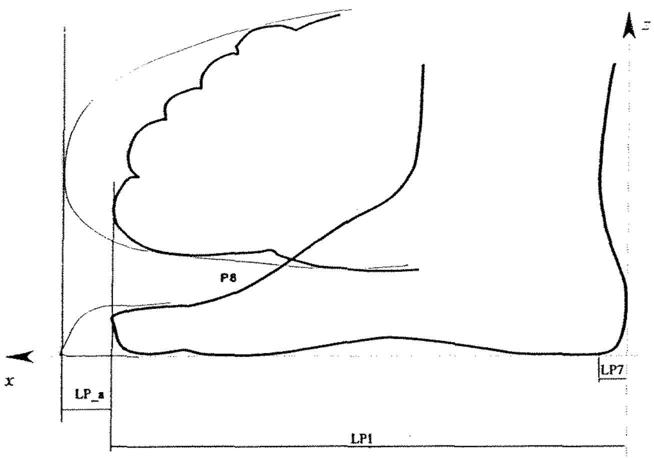

Figure V-2
Difference between shoe and foot lengths

It is a logical consequence that sandals, athletic footwear, dress shoes with pointed toe-part fitting the same foot (person) should have more or less different sizes. To reduce such confusions in retail manufacturers maintain a certain (but proprietary) standard in designing shoe lasts making the shoe sizing a rather nominal notation.[20]

[20]The real solution of this problem would be the introduction of a *direct* sizing system when the measured foot length (expressed in any units - preferable in mm) would appear on shoes, while the construction of the latter forepart would be of the problem of shoe last designers and footwear manufacturers. Several attempts were made by East-European countries in this regard, moreover ISO tried also to standardise shoe sizing under the Mondopoint project. The globalization of the world market, however, wiped out - at least for the time being - these efforts.

The "foot size" referred to hereafter in this report means what it really is: the length of the foot. In contrast the "shoe size" being the length of the insole will have to be created by adding the toe-part allowance and deducting the horizontal projection of the heel curve.

5.2. Differences within Basic Size Groups

Although each measured individual subject (foot) differs from others the five basic size groups created until now are considered as coherent sets of data whereas

a) *children:* major foot dimensions of boys and girls of the same age show no significant differences, so there is no need for distinction (i.e. separate parameters and rules) in designing shoe lasts, producing footwear and trading it;[21]

b) *boys* and *girls*: there is significant differences between dimensions of male and female feet of the same age (therefore different shoe lasts are required), but the common feature is that feet of individuals falling into these groups are still growing;

c) *men* and *women*: as a consequence of differences already in the youth age (see the previous paragraph) male and female individuals of the same height, age etc. have definitely different foot dimensions but these remain constant.[22]

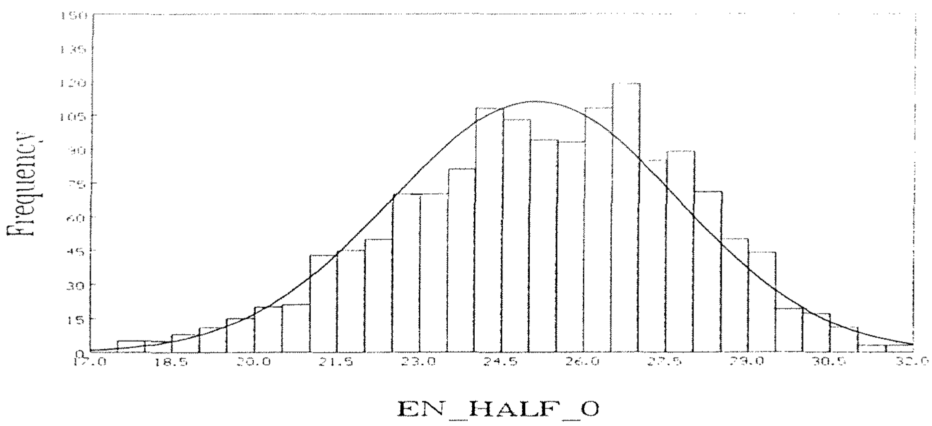

Figure V-3
Distribution of children foot lengths

The **children** size group is actually the largest (as usual) by its size and range of foot length. The distribution of major anthropometric parameters such as height, weight, foot length, foot width and ball girth has less similarity with the Gauss-type normal curve than in other size groups (*Figure V-3*). Even more important is that the pattern grading causes certain distortion of proportions so the sizes differing considerably from the (technical) middle or initial (master) size then the small and large sizes of the range will suffer from serious deformation. It is therefore strongly recommended to split the children size group into smaller ranges. The principle of deriving subsets of the children database, however, should be based on marketing and or social considerations. Normally it is sufficient to create 2-4 subgroups (e.g. small children of pre-school age up to 6 years, school children of 7-11 years age).

[21]There might be needs for differentiation between shoes produced for small boys and girls with regards to their appearance (shape, colour, upper construction, decorations etc.), but these would have no influence on sizes and proportions of shoe lasts.

[22]Unless drastic things (decease, accident, surgical intervention) happen.

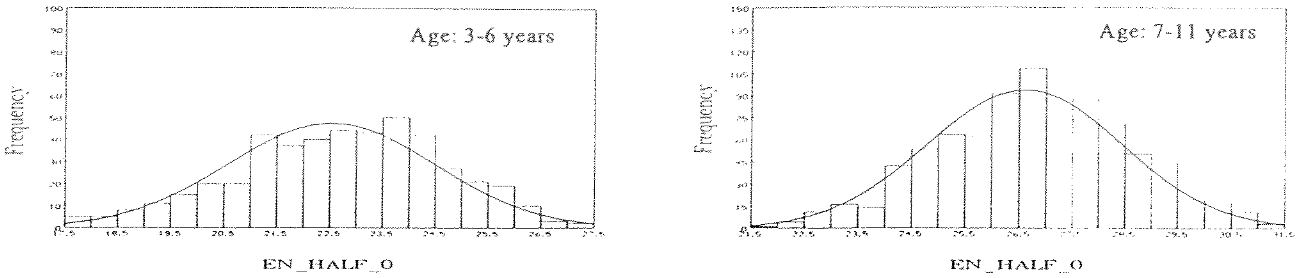

Figure V-4
Distribution of foot lengths in children subgroups

In the case of the uniform children group the size range covered 30 English half sizes, the middle size could be exactly I/13 (equal to II/0),[23] so the smallest and largest sizes would be 15 half sizes away from that. When the basic children (sample) population is split into subgroups as illustrated in*Figure V-4*, the distributions are closer to normal and the size ranges to be covered each group are 35% smaller. Further optimization can be made by splitting the basic group at a size which is common to both subgroups, whereas about 25% of the sizes would overlap. In our example that could be the size I/13 (12+13=25 English size unit). The revised middle sizes can be I/11 and II/2, whereas the size ranges would be 15 half sizes in both cases (*Figure V-5*).

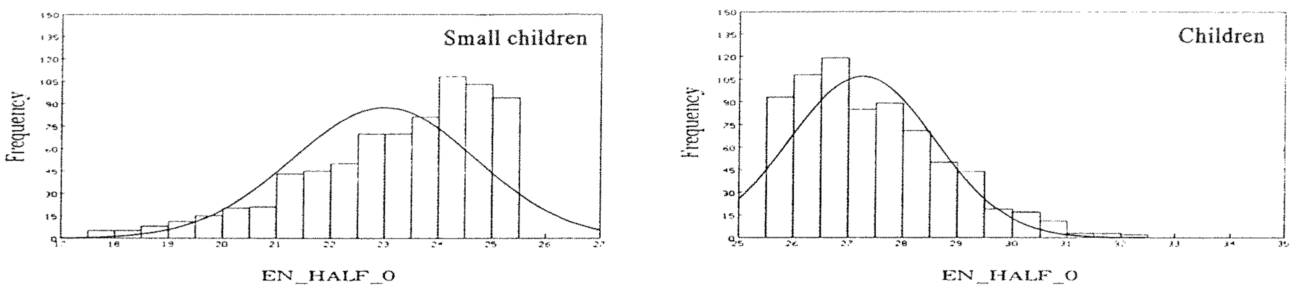

Figure V-5
Modified children subgroups

Another differentiation within the established size group may be the impact of **geographic** and/or ethnic (in fact anthropologic) regions. When measurements are made the actual region can be marked by a code: in the given survey India was divided into four geographic zones such as N(orth), W(est), S(outh) and E(ast).[24] The question is now whether people differ by their anthropometric features[25] (including foot sizes) by geographic regions? When the differences are significant (in terms of mathematical statistics) then different regions need footwear of specific size range or proportion or both.

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[23]The notation I/13 means size 13 in the first (I - children) group of the English shoe scale. This convention will be followed thereafter in this Report.

[24]For computational reasons beside these alphabetic numeric codes were also introduced with the following convention: N=1, W=2, S=3 and E=4.

[25]Anthropometric characteristics are usually the visible signs of more significant and relevant differences between certain ethnic or tribal groups.

The method[26] used for testing differences between samples is based on the *Student's t-distribution*:

$$t = \frac{|\bar{x}_1 - \bar{x}_2|}{\sqrt{\frac{s_1^2}{n_1} + \frac{s_2^2}{n_2}}} \qquad \text{(V-1)}$$

where $\bar{x}_i$ - average (best estimate of mean), s_i - empiric standard deviation (best estimate of variance or measure of dispersion), n_i - population of the sample (number of cases), i=1,2 - the index number of samples being compared. Whether the two samples show significant differences is decided by comparing the computed t value with the $t_{crit}= t(\varepsilon)$ critical value depending on the coefficient of freedom ($f=n_1+n_2-2$) at the desired confidence or allowed estimation error (ε) level.

The Student's t-test reveals differences between averages (middle sizes). If one would like to increase the reliability of retail sale, i.e. maximize the likelihood of serving every customer with well fittingfootwear with minimum size inventory, then the distribution of characteristic anthropometric measurements in regional subgroups should also be compared. This can be done by using the *F-test*:

$$F = \frac{s_1^2}{s_2^2} \quad \text{where} \quad s_1 \geq s_2 \qquad \text{(V-2)}$$

For given coefficient of freedom specific confidence level values (F_{crit}) are available in the respective reference books, while the notations are the same as before. If the difference happens to be significant between two regions then size ranges supplied there should be established independently.

For practical computations the database files FOOT*n*.DBF were transferred into set of spreadsheets FOOT*n*.WK4.[27] Statistical averages

$$x = \frac{1}{n}\sum_{i=1}^{n} x_i \qquad \text{(V-3)}$$

empiric (corrected) standard deviations

$$s = \frac{1}{n-1}\sqrt{\sum_{i=1}^{n} (x_i - \bar{x})^2} \qquad \text{(V-4)}$$

ranges

$$d = x_{max} - x_{min} \qquad \text{(V-5)}$$

of each measured and derived data were computed for each geographic regions within each basic size groups, as well as for the entire sample population of that particularsize group. (Here x_i is a particular value of subject

[26]Formulas presented below used for explanation and mathematical justification. The actual computations are made by using appropriate computer software (e.g. LOTUS or EXCEL spreadsheets, dBASE or CLIPPER database management programmes and/or specific mathematical statistical packages such as STATGRAPH, SPSS, STAT or SIMSTAT) use these.

[27]In this particular case LOTUS FOR WINDOWS (ver. 5.0) was used, but any modern spreadsheet software (e.g. MS EXCEL, QUATTRO PRO) would equally be suitable. These packages have facilities to convert database files automatically so after some simple operations and formatting the spreadsheet is ready for grouping data and performing elementary mathematical statistical analysis such as computation of means (averages), standard deviations, data ranges, t- and F-tests, linear correlations between two sets of data.

measurement in the sample, x_{min} and x_{max} are the minimum and maximum values of the subject measurement in the sample respectively, i=1,2,...,n and n is the number of observations in the sample.)

The Student's t-test was applied to compare each region with the entire size group, i.e. it was tested whether a geographic region differs significantly from the foot sizes representing the entire country. The computation results are summarized for the main parameters such as height, weight, foot length and size, ball width and the four measured girths in *Tables V-1.1* through *V-1.5*. Based on these tests the following conclusions can be made:

a) there are significant differences in weight of children living in different regions of India;
b) boys' feet in the North are smaller than in the South (the difference is 14 mm or three English half sizes) while ball widths and girths are larger (here the difference is 3 and 12 mm respectively which corresponds to 2 width groups);
c) girls' feet in the South are considerably longer and wider then in the North (the difference is 17 mm or almost 2 whole English sizes);
d) men's feet in the South are about 9 mm longer than in the North where required size range is also narrower;
e) women's body and feet anthropometric data seem to be very much the same throughout the country, i.e. there is no need to supply different size ranges or to design specific shoe lasts for women consumers living in different geographic regions of India.

When significant differences in foot dimensions are detected between regions then the basic size group should be split into subgroups accordingly and the further investigations should be carried out separately.[28]

4.3. Regression Analysis

Once coherent size (sub)groups have been established the main characteristics of feet should be determined. These are the set of measurements which can be used for identifying the sizes of each foot - and subsequently the corresponding (fitting) shoes - and as a basis for designing shoe lasts and footwear itself. In other words the task is to select those measurements which can determine all others whereas the number of basic measurements should be kept to the minimum. If there is a strong relationship between one of the measured body or foot dimensions and all others then the given property can be treated as the major size of the foot or shoe.

The history of shoemaking had selected the foot length, the ball girth and/or width as such basic data out of which all other parameters required for designing shoe lasts, shoe upper and bottom patterns can be derived either by using (simple) equations or appropriately constructed tables. A largenumber of anthropometric surveys made in several countries also proved that measurements oriented in the same direction of the space (axes of the Cartesian system of coordinates) correlate very well (e.g. instep or waist or heel measure have strong correlation with the ball girth). The foot survey should either verify the existing practice or find better, stronger, simpler and/or more reliable rules.

The ideal correlation and regression analysis would investigate all possible combinations of the data fields (measurements and personal data)[29] and various types of relationships (e.g. linear, quadratic or higher degree of paired, multi variable linear equations). It would, however, not be feasible as the majority of the paired comparisons are meaningless in footwear technology. Complicated rules - even with appropriate computer

[28]As the sample populations were rather small (especially when regional subgroups were separated), as not all regions were covered during the survey and as the reliability of collected data is questionable such separation - in spite of the above conclusions - was not implemented. For the same reasons there was no point to carry out the Snedecor's F-test.

[29]There are 88 *numeric* fields in the data record, so theoretically 88*87/2=3,828 pairs could be tested.

CHILDREN

REGION	HEIGHT	WEIGHT	L1	EN	N_HALF_	EN_INT_0	EN_GR	EN_HALF	EN_INT	FR	L2	W7	W8	BALLGIRT	HEELGIRT	ANKLEGIR	ABOVEANK	SAMPLE	
Average	119.3	22.3	209.53	24.77	25.0	25	1	13.0	13	31.9	210.95	89.82	87.56	174.62	240.41	155.26	198.45	1,463	
N	112.3	19.5	197.18	23.31	23.5	24	1	11.5	12	30.1	199.52	87.31	84.50	169.87	233.52	149.13	187.43	452	
W	106.4	16.3	186.25	22.02	22.5	23	1	10.5	11	28.4	186.68	77.95	75.04	170.21	228.23	147.30	140.85	141	
S	125.1	24.8	219.73	25.97	26.0	26	2	1.0	10	33.5	220.82	93.06	91.17	177.81	245.97	159.73	213.51	870	
St. dev.	13.8	6.8	22.15	2.62	2.6	2.6				3.3	22.01	9.06	9.21	17.58	25.77	16.06	32.23		
N	12.8	5.1	20.00	2.36	2.4	2.4				3.0	20.53	9.21	9.32	18.13	28.49	14.40	25.19		
W	11.4	3.9	16.16	1.91	1.9	1.9				2.4	16.18	7.47	6.88	15.78	23.38	12.43	18.81		
S	11.4	6.8	17.43	2.06	2.1	2.1				2.6	17.11	6.94	6.81	16.84	22.96	15.85	23.08		
Minimum	80	8	145.00	17.14	17.5	18	1	5.5	6	22	146.16	53.04	52.78	125	160	115	100		
N	80	10	145.00	17.14	17.5	18	1	5.5	6	22	147.44	63.69	60.72	130	160	115	120		
W	84	8	146.16	17.28	17.5	18	1	5.5	6	22	146.16	53.04	52.78	140	180	120	100		
S	97	10	172.84	20.43	20.5	21	1	8.5	9	26	172.94	71.83	67.84	125	170	117	130		
Maximum	155	50	267.38	31.61	32.0	32	2	7.0	7	41	268.01	125.01	117.28	240	310	205	300		
N	141	37	246.26	29.11	29.5	30	2	4.5	5	37	252.94	125.01	114.39	220	310	200	260		
W	137	29	219.24	25.91	26.0	26	2	1.0	1	33	220.65	96.25	92.80	210	290	180	210		
S	155	50	267.38	31.61	32.0	32	2	7.0	7	41	268.01	118.20	117.28	240	308	205	300		
Range	75	42	122.38	14.47	14.5	14		14.5	14	19	121.85	71.97	64.50	115	150	90	200		
N	61	27	101.26	11.97	12.0	12		11.5	12	15	105.50	61.32	53.67	90	150	85	140		
W	53	21	73.08	8.63	8.5	8		8.5	8	11	74.49	43.21	40.02	70	110	60	110		
S	58	40	94.54	11.18	11.5	11		11.5	11	15	95.07	46.37	49.44	115	138	88	170		
t-values																		%	*t_crit*
N	1.332	**3.022**	1.330	1.330						1.313	1.216	0.612	0.768	0.594	0.626	0.872	1.244	5.0	*1.960*
W	1.435	**4.333**	1.483	1.483						1.455	1.543	1.808	*1.979*	0.308	0.634	0.641	**4.844**	1.0	**2.576**
S	1.351	**2.843**	1.364	1.364						1.346	1.315	1.022	1.166	0.527	0.664	0.824	*2.066*	0.1	**3.291**

B O Y S

Table V-1.2

REGION	HEIGHT	WEIGHT	L1	EN	N_HALF_(	EN_INT_0	EN_GR	EN_HALF	EN_INT	FR	L2	W7	W8	BALLGIRT	HEELGIRT	ANKLEGIR	ABOVEANK	Sample
Average	149.3	39.3	247.00	29.20	29.5	30	2	4.5	5	37.6	248.81	105.80	103.30	205.41	284.95	180.87		607
N	147.2	37.8	238.75	28.22	28.5	29	2	4.5	5	36.3	241.35	104.01	101.24	212.85	299.17	186.01		253
S	150.8	40.4	252.90	29.89	30.0	30	2	5.0	5	38.5	254.15	107.07	104.76	200.10	274.79	177.20		354
St. dev.	11.5	10.2	16.49	1.95	2.0	2.0				2.5	16.13	8.42	8.06	18.04	27.12	19.73		
N	11.3	8.8	14.45	1.71	1.7	1.7				2.2	14.39	8.68	8.25	16.29	23.82	17.29		
S	11.4	10.9	15.29	1.81	1.8	1.8				2.4	15.16	7.99	7.59	17.34	24.65	20.53		
Minimum	110	18	199.48	23.58	24.0	24	1	12.0	12	30	204.76	80.80	80.04	160	190	130		
N	121	21	199.48	23.58	24.0	24	1	12.0	12	30	204.76	80.80	80.04	180	230	150		
S	110	18	204.74	24.20	24.5	25	1	12.5	13	31	205.02	87.47	82.48	160	190	130		
Maximum	179	77	287.10	33.94	34.0	34	2	9.0	9	44	287.35	127.90	123.36	265	380	260		
N	172	62	281.30	33.25	33.5	34	2	8.5	9	43	281.30	124.42	123.18	250	380	240		
S	179	77	287.10	33.94	34.0	34	2	9.0	9	44	287.35	127.90	123.36	265	380	260		
Range	69	59	87.62	10.36	10.0	10		10.0	10	14	82.59	47.10	43.32	105	190	130		
N	51	41	81.82	9.67	9.5	10		9.5	10	13	76.54	43.62	43.14	70	150	90		
S	*69*	*59*	*82.36*	*9.74*	*9.5*	*9*		*9.5*	*9*	*13*	*82.33*	*40.43*	*40.88*	*105*	*190*	*130*		
t-value																		
N	*2.476*	*2.224*	**7.309**	**7.308**						**7.289**	**6.687**	**2.770**	**3.350**	**5.903**	**7.649**	**3.805**		
S	*1.964*	1.544	**5.599**	**5.598**						**5.509**	**5.142**	*2.338*	*2.827*	**4.512**	**5.937**	*2.712*		

%	t_crit
5.0	*1.960*
1.0	2.576
0.1	3.291

GIRLS

Table V-1.3

REGION	HEIGHT	WEIGHT	L1	EN	N_HALF_	EN_INT_(	EN_GR	EN_HALF	EN_INT	FR	L2	W7	W8	BALLGIRT	HEELGIRT	ANKLEGIR	ABOVEANK	SAMPLE
Average	147.0	39.27	237.30	28.1	28.5	29	2	4.5	4.0	36.1	238.78	100.64	98.54	198.4	275.4	181.5	228.1	519
N	142.4	36.53	227.77	26.9	27.0	27	2	2.0	2.0	34.7	230.02	98.53	96.11	202.4	282.2	182.3	219.9	214
W	143.6	36.00	225.87	26.7	27.0	27	2	2.0	2.0	34.4	226.32	93.77	90.69	210.6	280.6	186.9	190.0	16
S	150.6	41.48	245.00	29.0	29.0	29	2	4.0	4.0	37.2	245.96	102.59	100.78	194.8	270.1	180.6	236.4	289
St. dev.	8.7	8.6	14.25	1.68	1.7	1.7				2.1	13.76	6.81	6.60	14.0	18.4	15.9	22.0	
N	8.0	7.2	12.01	1.42	1.4	1.4				1.8	11.69	6.50	6.08	12.8	15.0	15.3	17.7	
W	6.0	8.8	9.36	1.11	1.1	1.1				1.4	9.28	6.18	5.95	11.4	12.5	9.2	14.1	
S	7.6	8.9	10.91	1.29	1.3	1.3				1.7	10.83	6.34	6.01	13.9	19.1	16.6	20.8	
Minimum	120	20	190.24	22.49	22.5	23	1	10.5	11	29	191.10	80.64	79.26	160	220	140	160	
N	120	20	190.24	22.49	22.5	23	1	10.5	11	29	191.10	80.64	79.69	180	230	150	170	
W	134	25	202.42	23.93	24.0	24	1	12.0	12	31	202.48	82.73	79.26	190	260	170	160	
S	127	22	208.74	24.67	25.0	25	1	13.0	13	32	214.57	85.14	83.76	160	220	140	190	
Maximum	171	75	269.69	31.88	32.0	32	2	7.0	7	41	270.20	117.10	114.30	240	320	240	290	
N	160	55	262.16	30.99	31.0	31	2	6.0	6	40	262.35	116.61	111.87	240	320	230	260	
W	159	61	242.44	28.66	29.0	29	2	4.0	4	37	242.47	105.13	102.08	230	300	210	220	
S	171	75	269.69	31.88	32.0	32	2	7.0	7	41	270.20	117.10	114.30	229	320	240	290	
Range	51	55	79.45	9.39	9.5	9		9.5	9	12	79.10	36.46	35.04	80	100	100	130	
N	40	35	71.92	8.50	8.5	8		8.5	8	11	71.25	35.97	32.18	60	90	80	90	
W	25	36	40.02	4.73	5.0	5		5.0	5	6	39.99	22.40	22.82	40	40	40	60	
S	44	53	60.95	7.21	7.0	7		7.0	7	9	55.63	31.96	30.54	69	100	100	100	
t-values																		
N	**6.867**	**4.415**	**9.243**	**9.245**						**9.022**	**8.747**	**3.952**	**4.795**	**3.694**	**5.228**	0.664	**5.353**	
W	*2.225*	1.471	**4.718**	**4.717**						**4.738**	**5.199**	**4.371**	**5.182**	**4.169**	1.624	*2.243*	**10.405**	
S	**6.081**	**3.416**	**8.588**	**8.587**						**8.305**	**8.180**	**4.076**	**4.885**	**3.528**	**3.849**	0.762	**5.286**	

%	t_crit
5.0	*1.960*
1.0	2.576
0.1	3.291

MEN

Table V-1.4

REGION	HEIGHT	WEIGHT	L1	EN	N_HALF_(	EN_INT_0	EN_GR	EN_HALF	EN_INT	FR	L2	W7	W8	BALLGIRT	HEELGIRT	ANKLEGIR	ABOVEANK	SAMPLE
Average	164.2	60.0	262.12	30.98	31.2	31	2	6.2	6	39.8	263.37	114.02	111.17	225.4	304.5	193.9	250.0	490
N	163.2	56.3	255.58	30.21	30.4	31	2	5.4	6	38.8	256.64	110.44	107.68	232.7	324.1	202.6	247.6	136
S	164.6	61.4	264.64	31.28	31.5	32	2	6.5	7	40.2	265.95	115.39	112.51	222.5	296.9	190.5	251.0	354
St. dev.	6.9	10.5	12.88	1.52	1.5	1.6				2.0	12.61	7.68	7.21	18.4	27.5	19.1	23.6	
N	6.2	8.7	10.63	1.26	1.3	1.3				1.6	10.64	7.28	6.56	15.1	18.2	16.2	16.9	
S	7.1	10.8	12.79	1.51	1.5	1.5				1.9	12.34	7.38	7.00	18.7	26.8	19.1	25.6	
Minimum	141	36	228.51	27.01	27.5	28	2	2.5	3	35	231.24	94.07	91.12	180	230	140	170	
N	141	36	231.42	27.35	27.5	28	2	2.5	3	35	231.68	94.07	91.12	200	280	170	200	
S	146	37	228.51	27.01	27.5	28	2	2.5	3	35	231.24	96.99	95.43	180	230	140	170	
Maximum	185	100	304.50	35.99	36.0	36	2	11.0	11	46	305.36	133.41	131.91	280	380	240	325	
N	180	82	285.94	33.80	34.0	34	2	9.0	9	43	285.94	133.41	131.91	270	380	240	290	
S	185	100	304.50	35.99	36.0	36	2	11.0	11	46	305.36	133.33	131.76	280	380	240	325	
Range	44	64	75.99	8.98	8.5	8		8.5	8	11	74.12	39.34	40.79	100	150	100	155	
N	39	46	54.52	6.45	6.5	6		6.5	6	8	54.26	39.34	40.79	70	100	70	90	
S	39	63	75.99	8.98	8.5	8		8.5	8	11	74.12	36.34	36.33	100	150	100	155	
t-value																		
N	1.646	**4.161**	**6.054**	**6.054**						**6.095**	**6.256**	**5.009**	**5.362**	**4.783**	**9.859**	**5.365**	1.330	
S	0.801	1.901	**2.811**	**2.811**						**2.866**	**2.976**	**2.626**	**2.709**	*2.181*	**3.997**	*2.536*	0.531	

%	*t_crit*
5.0	*1.960*
1.0	2.576
0.1	3.291

WOMEN

Table V-1.5

REGION	HEIGHT	WEIGHT	L1	EN	N_HALF_	EN_INT_0	EN_GR	EN_HALF	EN_INT	FR	L2	W7	W8	BALLGIRT	HEELGIRT	ANKLEGIR	ABOVEANK	SAMPLE
Average	151.5	52.3	244.4	28.9	29.1	29.4	2.0	4.1	4.4	37.1	245.24	103.65	101.25	208.6	281.8	198.4	222.6	129
N	152.8	54.3	241.2	28.5	28.7	29.1	2.0	3.7	4.1	36.6	241.53	102.98	99.42	212.6	289.7	222.0	245.7	35
W	146.3	50.0	239.1	28.3	28.6	28.9	2.0	3.6	3.9	36.4	239.38	99.31	97.93	221.4	282.9	210.0	190.0	7
S	151.4	51.7	246.1	29.1	29.4	29.6	2.0	4.4	4.6	37.4	247.21	104.27	102.25	206.0	278.5	188.0	215.9	87
St. dev.	6.0	9.2	8.54	1.01	1.0	1.0				1.3	8.63	6.39	6.26	15.3	24.2	24.3	25.8	
N	5.7	8.7	6.82	0.81	0.8	0.7				1.0	6.80	4.86	4.61	12.5	26.0	17.7	27.3	
W	6.7	9.6	2.31	0.28	0.3	0.3				0.5	2.70	3.68	2.67	14.6	26.6	32.5	21.4	
S	5.8	9.2	8.93	1.06	1.1	1.1				1.4	8.90	6.92	6.77	15.5	22.4	17.9	17.5	
Minimum	138	36	223.88	26.46	26.5	27	2	1.5	2	34	224.05	90.17	87.46	170	200	150	150	
N	140	40	223.88	26.46	26.5	27	2	1.5	2	34	224.05	90.47	87.46	170	200	180	150	
W	140	38	235.48	27.83	28.0	28	2	3.0	3	36	235.60	93.15	93.14	200	230	180	170	
S	138	36	230.23	27.21	27.5	28	2	2.5	3	35	231.76	90.17	90.00	170	210	150	170	
Maximum	166	75	266.80	31.54	32.0	32	2	7.0	7	41	267.07	119.80	119.68	250	340	280	290	
N	166	75	259.26	30.65	31.0	31	2	6.0	6	39	259.31	114.70	111.48	240	340	260	290	
W	159	65	242.44	28.66	29.0	29	2	4.0	4	37	243.84	102.86	100.68	250	310	280	230	
S	165	74	266.80	31.54	32.0	32	2	7.0	7	41	267.07	119.80	119.68	240	328	230	282	
Range	28	39	42.92	5.08	5.5	5		5.5	5	7	43.02	29.63	32.22	80	140	130	140	
N	26	35	35.38	4.19	4.5	4		4.5	4	5	35.26	24.23	24.02	70	140	80	140	
W	19	27	6.96	0.83	1.0	1		1	1	1	8.24	9.71	7.54	50	80	100	60	
S	27	38	36.57	4.33	4.5	4		4.5	4	6	35.31	29.63	29.68	70	118	80	112	
t-values																		
N	1.196	1.180	*2.344*	*2.346*						**2.712**	**2.692**	0.676	1.915	1.581	1.626	**6.413**	**4.493**	
W	*2.011*	0.620	**4.546**	**4.530**						**3.261**	**4.610**	**2.891**	**2.886**	*2.261*	0.106	0.928	**3.885**	
S	0.129	0.482	1.412	1.414						1.543	1.609	0.666	1.100	1.228	1.024	**3.625**	*2.263*	

%	t_crit
5.0	*1.984*
1.0	**2.626**
0.1	**3.389**

programmes - would hardly be used by shoe designers and marketing department. Experience accumulated in foot surveys and the common sense provide useful guidelines on selecting interesting cases such as age, body height and weight, foot length, ball width and girth as dependant variables compared with the same set of measurements[30] (body height and weight with age in case of children, foot length with body height etc.) and dimensions of the same nature or direction (e.g. foot lengths with longitudinal linear measurements, widhs with girths).

The regression analysis may well be limited to linear relationships with the simple equation having the following form:

$$y = mx + b \qquad \textbf{(V-6)}$$

where y is the dependant, x is the independent variable, m (slope) and b (intersection with the vertical axis) are the parameters of the regression equation. The strength of the relationship is expressed by the coefficient of correlation (r). Particularly the coefficient of linear correlation may be computed by using the following formula:

$$r = \frac{\sum_{i=1}^{n}(x_i-\bar{x})(y_i-\bar{y})}{\sqrt{\sum_{i=1}^{n}(x_i-\bar{x})^2}\sqrt{\sum_{i=1}^{n}(y_i-\bar{y})^2}} \qquad \text{(V-7)}$$

The parameters in the equation of linear regression will then be:

$$m = \frac{s_y}{s_x} \qquad \textbf{(V-8a)}$$

and

$$b = \bar{y} - m\bar{x} \qquad \textbf{(V-8b)}$$

A relationship is considered strong in this report when the coefficient of correlation is higher than 0.7, i.e. $|r|>0.7$, while the level of confidence is 90% ($\varepsilon = 0.1$).

Figure V-6 is a scatterplot of linear regression in case of children and shows the relationship between foot length and body height. A relationship is considered strong in this report when the coefficient of correlation is higher than 0.7, i.e. $|r|>0.7$, while the level of confidence is 90% ($\varepsilon = 0.1$).

[30] Of course avoiding comparisons with themselves.

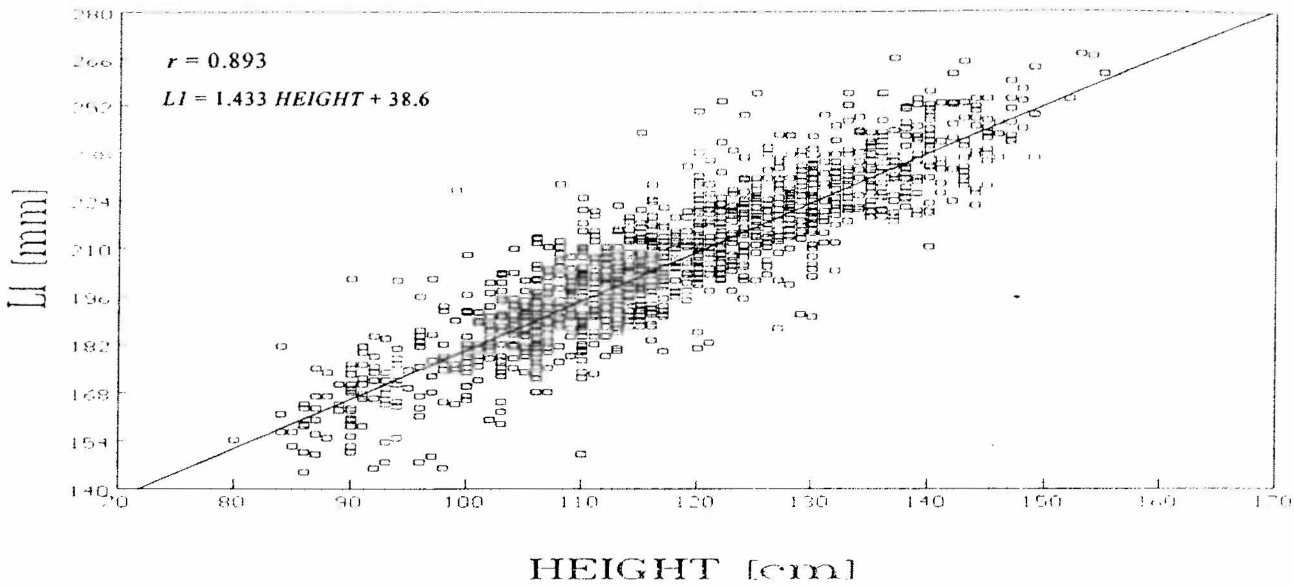

Figure V-6
Linear regression model

Experience of foot surveys shows that more sophisticated models might result only slightly stronger correlations. To prove this statement the ball girth (*BALLGIRT*) was tested as a function of the ball width (W7) in case of children (database FOOT1.DBF). The coefficient of linear correlation is r=0.6267 (see also *Annex E*). Equations of form

$$y = \sum_{i=0}^{d} a_i x^i \qquad \text{(V-9a)}$$

where d is the degree of the equation ($1<d<6$) offer somewhat better correlation: namely r=0.6287 in case of cubic (d=3), r=0.63 in case of 4th degree (d=4) and r=0.6315 in case of 5th degree (d=5) equations, but r=0.6267 in case of quadratic (d=2) relation - i.e. exactly as the linear regression. Inverse relation

$$y = \frac{a}{x} + b \qquad \text{(V-9b)}$$

produces r = 0.6171, logarithmic equation

$$y = a \ln x + b \qquad \text{(V-9c)}$$

gives r = 0.6244, exponential formula

$$y = e^{ax} + b \qquad \text{(V-9d)}$$

offers r = 0.6264 correlation.

Some measurements may depend on several others: in such cases multiple linear correlation may be stronger than any types of paired relation. We are looking for an equation of the following form:

$$y = b + \sum_{i=1}^{k} a_i x_i \qquad \text{(V-10)}$$

where a_i is the coefficient for the *I*-th independent variable, b is a constant, k is the number of independent variables.

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Results of the linear regression analysis over the five size groups are given in *Annex E*. Based on these data the following conclusions can be made:

a) the impact of age, weight and (body) height is decreasing by age: these characteristics are relevant in case of children and boys, but have no significance for the adult population (i.e. the volume of women's and men's feet does not depend on the body structure);
b) the two types of foot length (*L1* and *L2*) are interchangeable so any of them can be used for defining the major dimension of feet and footwear;
c) linear measurements of the same directions show high correlation therefore they may well be computed from the foot length ;
d) there are two major directions in foot: length and width, while measurements in the third direction (height) have no strong linkage with other;
e) foot length and width are not correlated so to satisfy the local population with well fitting (healthy) footwear more than one width/girth should be made available for the same lengths;
d) unfortunately girths do not correlate with the respective widths or heights therefore ball girth should be used as one of the important volumetric property of feet and shoes;
e) since foot length correlates with more other measurements than ball width or girth it should be the main foot dimension for size indications;[31]
f) multiple linear regressions do not show much stronger relations than paired;
g) the regression analysis proves again that the measurement process was far from thorough - especially in case of girls and women.

The foot survey normally produces some "by-products", i.e. useful statistical data for other scientific disciplines or industries (e.g. anthropology, demography, ergonomy, apparel manufacturing). *Table V-2* demonstrates those relations between personal characteristics which happened to be strong (r>0.7).

Table V-2

Linear regression between personal characteristics

Size Group	x		y		m	b
1 Children	AGE	*year*	HEIGHT	*cm*	5.1	76.5
			WEIGHT	*kg*	2.2	4.9
			L1	*mm*	7.7	148.5
	HEIGHT	*cm*	WEIGHT	*kg*	0.4	-27.9
			L1	*mm*	1.4	38.6
	WEIGHT	*kg*	L1	*mm*	2.6	150.6
2 Boys	HEIGH	*cm*	WEIGHT	*kg*	1.1	84.5
			L1	*mm*	1.4	38.6
	WEIGHT	*kg*	L2	*mm*	1.1	205.0

[31]Due to the globalization of the international trade and the heavy involvement of the Indian shoe industry in export it would be impossible to use any other dimension either.

5.4. Size Ranges

The foot length is regarded as the major measurement for expressing its size. The English and the French size systems dominate the word market and are used in India as well for indicating internal dimensions of footwear. The next task is to determine - based on this fresh foot survey - size ranges which offer acceptable coverage of the local population.

The mathematical statistical analysis of the size group databases (as discussed earlier in the Report) indicated that the (Gauss-type) of normal distribution describes the sizes of feet. *Figure V-7* illustrates the results of the present foot survey whereas foot lengths are expressed in English half sizes (*EN_HALF_0*).

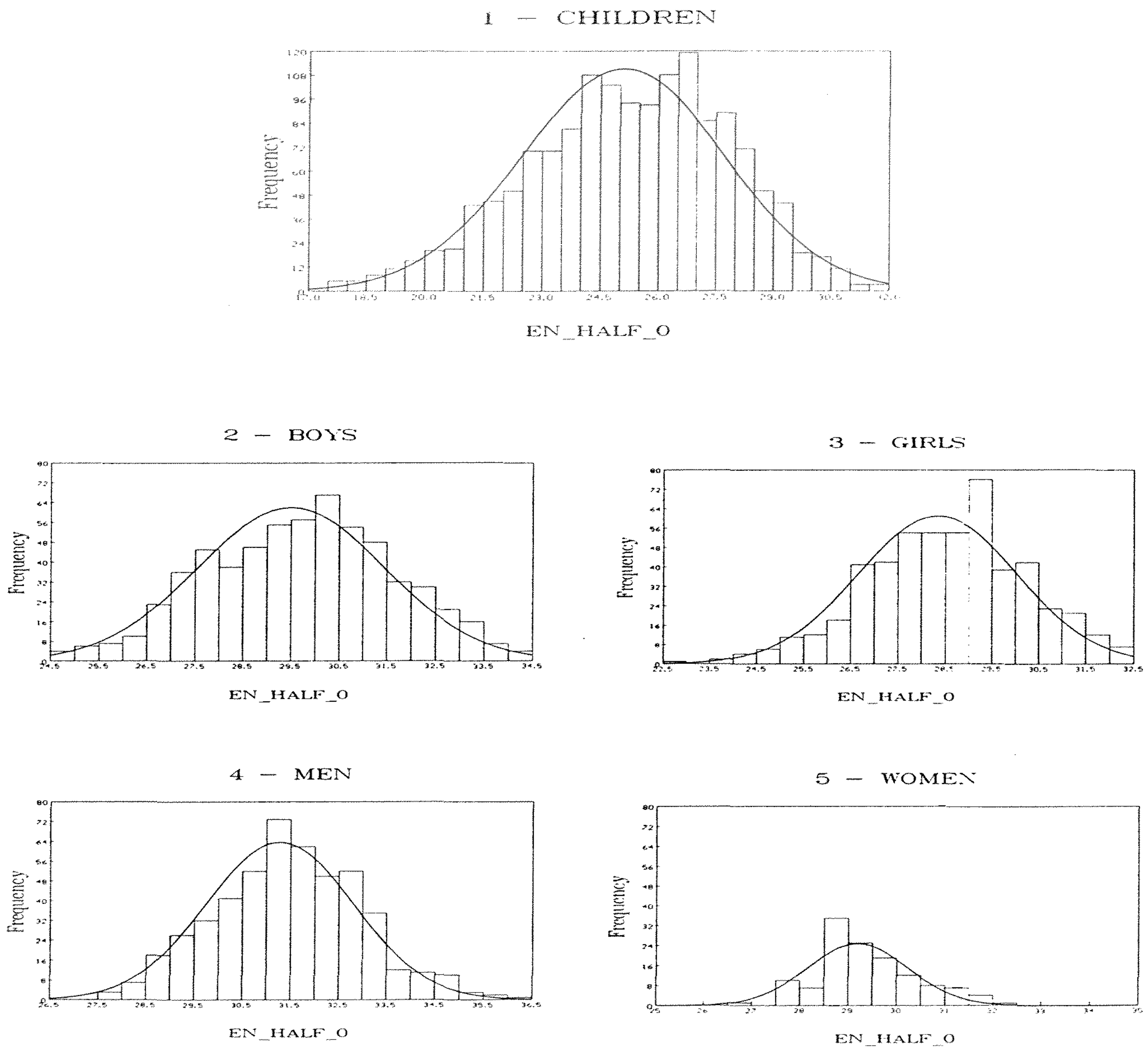

Figure V-7
Size distributions by foot length

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The creation of longitudinal size ranges is based on the assumption that the principal measurement follows the normal distribution (the validity of such a statement is seen on*Figure V-7*); its general equation has the following form:

$$y = \frac{1}{s\sqrt{2\pi}} e^{-\frac{(x-\bar{x})^2}{2s^2}} \qquad \text{(V-11)}$$

The computed middle size$\bar{M} = \bar{x}$ (where x is *L1* or *EN* or *FR*) should be a rounded to M - the nearest (normally larger) valid value of the size scale which is ½ or 1 English size or 1 French point.[32]

$$M = \text{Round}(\bar{M},\Delta z) \qquad \textbf{(V-12)}$$

where Δz is the increment in the size scale. Other sizes in the range are generated by simply adding in succession the size increment (expressed in the unit of the given system) to the middle size. Thus the linearsize scale[33] is generated by the formula:

$$Z_i = M \pm i\Delta z \qquad \text{(V-13)}$$

where i is an integer ranging from 1 to k (see below).

The range of sizes depends on the desired level of coverage, i.e. what percentage of the local population (as potential consumers of footwear) should be provided with footwear coming from mass production. The area under the distribution curve surrounded by vertical lines at $\bar{x}\pm\lambda s$ is proportional to coverage.[34] If λ=3 then 99.8%, if λ=2 then approximately 90% of the population will findshoes of the needed size in retail shops (*Figure V-8* illustrates this on the example of men foot). Knowing M (rounded up) middle, s standard deviation, Δz increment used for building the size scale and taking into consideration the rule used for standardizing normal distributions the following relationship can be established:

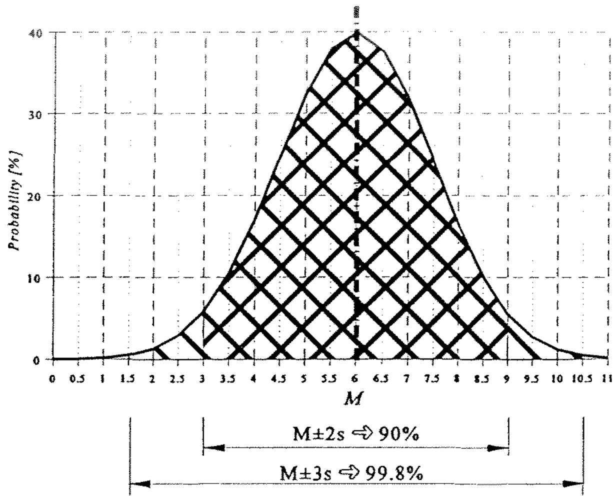

Figure V-8.

$$\lambda_i = \frac{Z_i - M}{s} \qquad \textbf{(V-14)}$$

Since the i-th size should accommodate foot lengths falling in the intervalof Z_i-Z_{i-1} the coverage of that particular size is computed by using the following equation:

---

[32]It would be 5 or 7.5 mm in the MONDOPOINT system.

[33]It is obvious that the elements of the size scale form an arithmetic progression.

[34]Theoretically full (100%) coverage can be achieved only when $\lambda=\infty$ - then this area is equal to 1.

$$C_i = \frac{\lambda_i - \lambda_{i-1}}{\frac{y_{i-1} + y_i}{2}} = \frac{2(\lambda_i - \lambda_{i-1})}{y_{i-1} + y_i} \qquad \text{(V-15)}$$

where y_i is computed by using equation (11) whereas x is replaced with the actual size Z_i.

To find the appropriate size range a spreadsheet similar to that illustrated in *Annex F-1* can be used (the actual data indicated in this table refer to the men size group resulted by the present survey). The basic input data consist of the computed average foot length, the standard deviation, the size increment and the batch volume.[35] After having entered the six input data the system computes automatically all characteristics of the respective normal distribution and produces the recommended size range together with the number of pairs to be supplied of each sizes involved. As the actual computation is made on a discrete and the algorithm includes a number of rounding functions, the results (total number of pairs and the actual coverage) will always differ slightly from the desired (targeted) values indicated by inputs. Therefore the final adjustment may need to be made manually taking into consideration the deviation of the selected middle size from its computed (see the last column in *Annex F-1*).

After having applied the same procedure to all other size groups the proposal for size ranges was prepared. Recommended length ranges for the English half size scale is shown in *Table V-3*, ranges for whole English size and French point scales are attached as *Annex F-2*.

When 90% size coverage is mentioned above (and in *Annex F-2*) it is to be understood with regards foot (shoe) length only. The low correlation between longitudinal and other dimensions perpendicular to it (see column *L1* in relation with *W7*, *W8* and *BALLGIRT* in *Annex E*) indicates that providing consumers with footwear of appropriate range in length will not be sufficient as feet of the same length have too widespread range with respect to their (ball) girths/widths. That is why in many countries shoes are marketed in different **width groups.**[36] When footwear of different width are not available for the same length then people with wider feet are forced to purchase shoes of larger sizes while those having narrower feet will have to wear too wide shoes. In both cases feet may suffer (especially if shoes smaller in their lengths are worn on feet narrower feet to avoid too loose fit), but certainly shoes will go out of their shape much faster than in case of normal fit and their durability will also be reduced.

Analysis of the main statistical descriptives such as average and standard deviation computed for a given subset of feet falling into the same (length) size will show the need for creating width groups. *Annex G* show the results of such computation. Both tables were prepared for English half sizes: *Annex G-1* was created on basis of ball girths, while *Annex G-2* is based on foot widths. The number of width groups required to cover the needs of the local population is computed by using the following formula:

$$w_g = \frac{\lambda s}{\Delta x} \qquad \text{(V-16)}$$

where w_g is the number of width groups, s is the standard deviation (of girth or width), Δx is the difference of ball girths or width of two (adjacent) groups. Of course the latter depends on the size system used for measuring

[35] A batch may be a complete order or its fraction, the number of pairs in the production lot, the amount of footwear kept together in handling, packaging, shipping, transporting, storing, ordering etc. (The footwear industry uses the typical batch sizes are 6, 10, 12, 60, 100, 120, 144, 500, 600, 1000 pairs.)

[36] Retailers in USA offer the same style in different widths. Many of the leading European shoe manufacturers are specialized on certain widths and customers learn gradually that which brands fit best to their specific widths requirements.

Recommended size ranges for Enlish HALF size system

English size		Children		Boys		Girls		Men		Women	
Linear	*Normal*	%	*Batch*	%	*Batch*	%	*Batch*	%	*Batch*	%	*Batch*
16.5	4.5	0.040									
17.0	5.0	0.073									
17.5	5.5	0.128									
18.0	6.0	0.216									
18.5	6.5	0.352									
19.0	7.0	0.554									
19.5	7.5	0.840									
20.0	8.0	1.229									
20.5	8.5	1.734									
21.0	9.0	2.361	3	0.001		0.001					
21.5	9.5	3.099	3	0.003		0.003					
22.0	10.0	3.924	4	0.008		0.011					
22.5	10.5	4.792	5	0.020		0.031					
23.0	11.0	5.645	6	0.047		0.082					
23.5	11.5	6.415	7	0.104		0.199					
24.0	12.0	7.031	8	0.217		0.442					
24.5	12.5	7.432	9	0.426		0.900		0.001		0.001	
25.0	13.0	7.579	**9**	0.783		1.680		0.004		0.006	
25.5	0.5	7.454	9	1.348		2.874		0.013		0.040	
26.0	1.0	7.071	8	2.176		4.510	5	0.041		0.194	
26.5	1.5	6.471	7	3.292	4	6.490	7	0.116		0.747	
27.0	2.0	5.711	6	4.668	5	8.563	10	0.298		2.270	
27.5	2.5	4.862	5	6.204	7	10.361	12	0.690		5.461	6
28.0	3.0	3.992	4	7.730	9	11.496	**13**	1.438		10.417	11
28.5	3.5	3.162	4	9.028	10	11.697	13	2.694		15.769	17
29.0	4.0	2.416	3	9.883	**10**	10.914	12	4.543	5	18.957	**21**
29.5	4.5	1.780		10.142	11	9.338	10	6.893	8	18.104	20
30.0	5.0	1.265		9.756	11	7.327	8	9.415	10	13.734	16
30.5	5.5	0.867		8.797	10	5.272	6	11.573	13	8.273	9
31.0	6.0	0.574		7.436	8	3.478	4	12.803	**14**	3.953	
31.5	6.5	0.366		5.891	7	2.104		12.750	14	1.496	
32.0	7.0	0.225		4.375	5	1.167		11.427	13	0.448	
32.5	7.5	0.134		3.046	3	0.593		9.218	11	0.106	
33.0	8.0	0.076		1.988		0.277		6.693	7	0.020	
33.5	8.5	0.042		1.216		0.118		4.373	5	0.003	
34.0	9.0	0.022		0.697		0.046		2.572			
34.5	9.5			0.374		0.017		1.361			
35.0	10.0			0.189		0.005		0.648			
35.5	10.5			0.089		0.002		0.278			
36.0	11.0			0.039				0.107			
36.5	11.5			0.016				0.037			
37.0	12.0			0.006				0.012			
37.5	12.5			0.002				0.003			
38.0	13.0			0.001				0.001			
		99.936	100	99.999	100	99.999	100	100.000	100	100.000	100

Remark: Targeted coverage is 90%.
Middle sizes are highlighted

foot length, but also varies by countries and manufacturers. The most commonly used increment in girth is 5 mm, at the same time there are systems using 6 mm (e.g. MONDOPOINT), 7 mm for girth or 3 mm for width (e.g. AKA64/WMS).[37]

Based on the computations and taking into consideration the international experience two alternative width ranges are recommended for India:

a) when the ball girths is used for determining width groups then one alternative (4*s*/7) would provide 90% width coverage with 7 mm differences between width groups, the other (2*s*/6) would provide 75% width coverage with 6 mm increment between groups;

b) when the ball width is used then one alternative is based on providing 90% coverage with 4 mm differences, while the other would give 75% coverage with 3 mm increments.[38]

The real coverage is the product of the coverages in length and width. Thus the first proposed option offers 81% (0.9*0.9=0.81), the other 67.5% (0.9*0.75=0.675) coverage: the number of width groups to be retailed varies between 4 and 8. This may be reduced if the same computation is made for (sub)regions where deviations in width and (or) girth are smaller.

5.5. Grading Parameters

When grading shoe lasts (and subsequently basic shells, upper and other component patterns) two increments are used as parameters: the difference between girth/widths of two adjacent length (sizes) of the same width groups and the difference between girth/width two (adjacent) width groups of the same length (size).

The increment of girth/width by length sizes will depend on the sizing system (unit of measurement) used. It is, however, sufficient to analyse anthropometric data in relations with one system; the results then can easily be converted for other systems. Data are first grouped by foot length expressed in a given size system (in our case in English half sizes), then average ball girths and widths are computed for each size. Now the increments in girth/width can be computed for each adjacent pair of length sizes: the weighted average of these figures will give the computed (theoretical) incrementby (English half) sizes. All this can be expressed by the following formula:

$$\Delta\bar{g}_1 = \frac{\sum_{i=Z_{min}+\Delta z}^{Z_{max}} n_i(x_i - x_{i-1})}{N} \qquad \textbf{(V-17)}$$

where Z_{min} and Z_{max} are the smallest and largest relevant[39] foot length sizes in the range respectively, Δz is the size increment of the length scale, n_i the number of measured feet falling into the ith size, x_i is the average girth or width of feet of the ith size.

---

[37]Shoe last manufacturers (e.g. FAGUS, SEIDL) are using their own standards: some of these are adopted by almost all shoe producers getting their shoe lasts from that particular company. In some countries the increments are prescribed by national standards (e.g. the former Soviet Union).

[38]The notation 4*s*/7 is to be understood as follows: the width range would cover ±2*s*=4*s* interval (corresponding to 90% coverage) whereas this interval is broken into width groups differing from each-other by 7 mm in ball girth.

[39]Theoretically the smallest size is the one which occurs among the measured feet. Relevant sizes are those which have sufficient measurements for statistical computations or which fall into the length size range set for achieving a given level of coverage in foot/shoe length.

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Computations can be carried out in a spreadsheet similar to that shown in *Annex H*. The theoretical increment of ball girth by English half sizes ranges from 1.27 mm (girls) to 2.43 mm (men), while the increment of ball width varies between 0.57 mm (women) and 1.48 mm. The FAGUS standard is based on 2.5 mm, the American system uses 1/8"=3.175 mm increment in ball girth practically for all size groups. The AKA64 standard prescribes a variable increment of ball girth which ranges from 1.5 mm (for small children) to 5.0 mm (for boys) for 1 French point length size difference which corresponds to 0.94-3.17 mm for English half sizes. East-European countries apply 2.5 mm ball girth increment for half English size difference in length.

Increments for other shoe size systems may be computed similarly, but there is a simpler and fasterwas to arrive to the result:

$$\Delta g_1 = \Delta g_0 \frac{\Delta z_1}{\Delta z_0} \qquad \textbf{(V-18)}$$

where Δg_1 is the required increment in the target size system with Δz_1 increment of the length scale, Δg_0 and Δz_0 are the known values (all expressed in mm). E.g. if 2.5 mm is adopted for girth increment for an English half size then Δg_0=2.5 mm, Δz_0=4.23 (1/6"), then the corresponding increment in the French point system (Δz_1=6.67 mm or 2/3 cm) will be Δg_1=3.94 mm≈4 mm.

Based on the foot survey results made and taking into consideration the international practice it is recommended to adopt the increments shown in *Table V-4* in India.

Table V-4

Ball girth and width increments in *mm*

Size group		Ball girth			Ball width		
		By length (Δl_g)		By width group	By length		By width group
		*English size**	*French point*		*English size**	*French point*	
1	Children	5.0	4.0	6.0	1.7	1.5	2.0
2	Boys	3.0	2.5	6.0	1.0	1.0	2.0
3	Girls	3.0	2.5	6.0	1.0	1.0	2.0
4	Men	5.0	4.0	8.0	1.7	1.5	2.5
5	Women	5.0	4.0	8.0	1.7	1.5	2.5

Remark: *The parameters refer to size increments of *whole* English sizes

Chapter VI

DESIGN OF SAMPLE SHOE LASTS

6.1. Conversion of Foot Dimensions into Shoe Last Measurements

The shoe last is a special, but most important tool used in shoemaking. Its shape gives the form of the footwear, its dimensions determines the internal volume of the shoe. The shoe last is an object which transforms the shape and dimensions of the human foot into a well fitting shoe. Therefore even the basic measurements of the foot,[40] the shoe last and the (inner cavity of) shoe are not exactly the same. The shoe last length size (z_{last})can be derived by using the next equation:

$$z_{last} = \mathrm{Round}(l_{foot} - l_{hp} + \Delta l_g + \Delta l_a, \Delta z) \qquad \textbf{(VI-1)}$$

where Round is the rounding-up function, l_{last} is the foot length (*L1*) in mm, l_{hp} is the heel point position (*LP1*) in mm, Δl_g is the growth rate of (children and youth) foot within the targetedservice period of the shoe (normally half year) in mm/time, Δl_a is the allowance foot movement and toe shape in mm (these two allowances are indicated as LP_a on *Figure V-3*), Δz is the size unit used for length in mm/size. Using the basic data derived from the foot measurement survey in India the computation resulted the middle sizes for shoe lasts of the five size groups as indicated in *Table VI-1* below.

Table VI-1

Middle (length) sizes of shoe lasts

Size group		Average foot length	Heel point position	Growth rate	Allowance for forepart	Shoe (last) length size	
		l_{foot}	Δl_{hp}	Δl_g	Δl_a		
		mm	*mm*	*mm/½ year*	*mm*	English size	French point
1	Children	209.5	3.0	4.2	5.0÷7.0	II/½	32
2	Boys	247.0	4.0	2.3	5.0÷10.0	II/4½	38
3	Girls	237.3	4.0	0.0	5.0÷10.0	II/3	36
4	Men	262.1	5.0	0.0	5.0÷15.0	II/6	39
5	Women	244.4	5.0	0.0	5.0÷15.0	II/4	37

Remark: The sign ÷ indicates a range (from-to).

[40] In case of a mass foot survey the foot dimensions are represented by the statistical average of feet falling into the given length and width group.

Unfortunately there is no scientific algorithm for transforming girth and width measurementsof feet into the same of shoe lasts. The conversion should take into accountthe sensibility of human foot (especially against constant pressure), the natural change of the foot volume and dimensions during the walking process and during the calendar day, the flexibility and elasticity of shoe construction (especially materials used for the upper and lining). Nevertheless based on the experience accumulated by shoe last designers and shoe fitters(retailers) over the past decades the following-simple basic rules may be adopted:

a) the ball, waist, instep and heel girths of shoe lasts are 5-10 mm less than those on (normal healthy) foot, but in case of small children it is recommended to keep the difference near to nil (zero);
b) the shoe last ball width is about⅓ of the shoe last ball girth value (the same relation is applicable in case of the respective increments as well);
c) the ball width of the bottom (insole) pattern of shoe lasts is normally 10% less than the foot bal width;
d) the heel width of the bottom (insole) pattern of shoe lasts is normally 5% less than the heel width of the foot projection.

5.2. Width Tables

The ultimate aim of any (mass) foot surveys is to create and recommend appropriate tables consisting basic-
measurements for designing shoe lasts of all si ze combinations which may occur in (mass) production of footwear. To create a table one-needs to

a) decide on the *length size system* to be used for marking shoe lasts and footwear, i.e. select the size unit and the increment used for lengths;
b) decide on *codes* to be used for indicating width groups (see below);
c) establish its *starting point* (cell), i.e. the starting or central length size, width group and the corresponding girth or width value derived from statistical analysis of the foot measurement survey data;
d) determine the *increments* in girth or width values by length increment and width groups.[41]

As far as **width coding** is concerned there are three systems which have been widely used in the world footwear industry and retail. The French point and all metric systems (including MONDOPOINT) use numeric (integer) codes starting from 1 with increment of 1. The AKA64/WMS system proposed specifically for children footwear in Germany uses Roman numbers from I to V whereas the three middle groups have capital letters expressing the character of widths; namely II=S for *s*mall, III=M for *m*iddle and IV=W for *w*ide. The English system uses alphabetic codes (capital letters) starting from A (this is practically the same as the former system, i.e. the letters may be replaced with integer numbers: A=1, B=2, ..., L=12). The American system is rather complicated: the codes A, B, C, D and E are used for middle width groups, while smaller width are identified as AA, AAA, AAAA in decreasing order, the larger widths are indicated as EE and EEE in increasing order.

The actual girths or widths of middle sizes of different size groups do not makeup a coherent arithmetic progression[42] as their starting points and increments are different. Therefore normally separate width tables are

[41]All traditional systems use increments which are constant throughout the given size group. However some modern systems have been introduced with variable increments, whereby the increase in ball girth or width depends on sizes and width groups (e.g. it is 4.5 mm between width-groups for French size 18 and 7 mm between width IV and V for French size 42 - all for ball girth in the AKA64/WMS system).

[42]A leading shoe last manufacturer (FAGUS in Germany) uses uniform tables for French point (16-47), English (I/½-II/12) and metric(1-32 cm) shoe size systems respectively.

made and used for different size groups. Using the survey results it is recommended to set starting (central) values of bal girth and width of middle sizes for width tables of the established five size groups according to *Table VI-2* (next page). It is recommended to refer to these middle width groups as (code) 6 or F, whereby smaller and larger groups would have smaller and larger digital or alphabetic codes respectively.

Table VI-2

Central girth and width values for middle sizes in *mm*

Size group	Length size		Foot		Shoe last	
	English	French	Ball girth	Ball width (plantar projection)	Ball girth	Ball width (plantar projection)
	size	*point*	*mm*	*mm*	*mm*	*mm*
1 Children	II/½	32	176.0	90.1	172	81
2 Boys	II/4½	38	206.1	105.5	200	95
3 Girls	II/3	36	198.7	99.7	192	90
4 Men	II/6	39	223.0	114.3	215	102
5 Women	II/4	37	210.7	104.1	200	94

The actual ball girth or width value of any particular size-width combination may be computed by using the following formula:

$$g_{z,w} = g_0 + \frac{z-z_0}{\Delta z}\Delta l_z + \frac{w-w_0}{\Delta w}\Delta l_w \qquad \textbf{(VI-2)}$$

where $g_{z,w}$ is the ball girth (or width) of the shoe last of size z and width group w, g_0 is the ball girth (or width) middle size shoe last, z_0 and w_0 are the size and width group of the middle size shoe last respectively, Δz and Δw are the increments in the size and width group scale (normally Δz=0.5 or Δw=1 for English sizes and French points, Δz=5 or Δz=7.5 for the MONDOPOINT system, Δw=1), Δl_g and Δl_w are the increments in ball girth (or width) by sizes and width groups respectively.

Alternatively the theoretic starting points of width tables may be derived for a somewhat simpler computation method. For this the *theoretical starting point* (c_g or c_w at z=w=0) of the table should be found for each size group. The above equation may easily be rearranged:

$$c_g = g_0 - \frac{z_0}{\Delta z}\Delta l_z - \frac{w_0}{\Delta w}\Delta l_w \qquad \textbf{(VI-3a)}$$

Substituting the recommended values indicated in *Table V-8* and *Table VI-2* into this formula constants shown in *Table VI-3* can be established.

Table VI-3

Constants for computing ball girth and width

Size group		Ball girth (c_g)		Ball width (c_w)	
		English size*	French point	English size*	French point
1	Children	8.5	8.0	22.6	21.0
2	Boys	75.5	69.0	53.5	45.0
3	Girls	72.0	66.0	50.0	42.0
4	Men	14.0	13.0	48.5	28.5
5	Women	9.0	6.0	32.5	23.5

Remark: *The initial length and the children sizes are to be included (e.g. size II/4=12+13+4=29).

The ball girth or width may now be computed by using the respective simple linear equation:[43]

$$g_{w,z} = z\Delta l_z + w\Delta w + c \qquad \textbf{(VI-3b)}$$

where $c=c_g$ for computation of ball girth and $c=c_w$ for ball width.

Width tables are normally two dimensional with cell values depending on two parameters shown in rows and columns. The traditional arrangement is that rows refer to length sizes of a given size system, while columns correspond to width groups. The cells indicate ball girths or ball widths in millimeters or inches. Using the above algorithm, parameters and constants it is easy to generate such tables (spreadsheet software is especially suited for this purpose). *Annex J* consists recommended width tables derived from the foot survey.

5.3. Design Documentation for Sample Shoe Lasts

Practically all average values produced by statistical analysis of the foot survey data can be used for designing the corresponding sample shoe last. However, since these values represent foot measurements, they should be transformed into shoe last measurement. As it has already been mentioned there is no scientifically proven methodology and (or) set of coefficients for such conversations. Moreover mass shoe production is based on creation of middle sizes which are then graded into the desired (or ordered) size range. For this purpose it is sufficient to use the basic measurements of the middle size and apply respective proportions and parameters derived from the foot survey.

To produce the set of basic measurements for sample shoe last design the available databases should be used again. The first task is to select those data records which fall into the middle (foot) sizes of each size groups and compute the average values of the important measurements. *Table VI-4* (see next page) consists these *foot* measurements. Rules for conversion into shoe last measurements are the same as listed in paragraph 5.2 above.

[43] This is similar to the *Zibin* formula used in East-European countries.

Table VI-4

Basic data for sample shoe last design

Measurement	Unit	Children	Boys	Girls	Men	Women
Foot size	English	I/13	II/4½	II/3½	II/6½	II/4½
	French	32	38	36	40	38
Shoe last size	English	II/½	II/4½	II/3	II/6	II/4
	French	32	38	36	39	37
L1	mm	209.4	47.8	239.0	264.5	247.3
L2	mm	210.7	249.4	240.1	265.6	248.4
W1	mm	57.8	66.7	64.8	72.3	68.1
W2	mm	40.7	46.1	45.5	51.6	48.0
W3	mm	49.4	54.5	54.2	64.3	60.1
W4	mm	-38.1	-48.3	-44.6	-47.3	-42.8
W5	mm	48.7	51.0	51.4	61.9	58.2
W6	mm	-39.3	-46.3	-43.5	-46.9	-42.8
W7	mm	90.1	105.6	100.5	113.7	105.1
W8	mm	87.5	102.7	98.8	111.5	102.9
C1	mm	-17.8	-23.0	-17.9	-18.4	-14.0
C2	mm	41.9	42.4	43.2	51.7	49.2
B5	°	82.1	81.4	80.7	81.7	82.4
B6	°	85.3	84.6	84.8	85.3	85.0
LP1	mm	43.3	52.0	47.9	44.9	50.4
LP2	mm	93.7	110.7	109.8	113.9	113.0
LP3	mm	37.8	162.8	161.8	174.0	165.5
LP4	mm	151.7	183.7	173.0	192.7	180.4
LP5	mm	144.7	173.2	167.4	183.3	172.9
LP6	mm	176.3	209.7	203.4	222.8	209.5
LP7	mm	23.3	22.4	22.9	23.4	24.2
H4	mm	50.5	58.1	57.9	66.8	58.2
H5	mm	34.0	37.5	37.0	40.6	39.5
H6	mm	27.2	29.5	29.9	34.1	32.8
G1	mm	104.5	124.4	121.0	134.7	125.9
G2	mm	67.0	75.7	75.8	83.8	79.2
G3	mm	35.0	39.9	37.6	42.1	39.8
BALLGIRT	mm	176.0	204.2	195.8	231.7	209.7
HEELGIRT	mm	240.6	283.3	271.8	311.4	289.5

Sample shoe lasts are built on the **bottom pattern** (this actually corresponds to the shoe insole pattern when normal cemented technology is applied in shoe assembly). The scheme of constructing the shoe last bottom pattern is illustrated on *Figure VI-1* and described below:[44]

1. Draw the longitudinal (x) and width (y) axes - by definition they are perpendicular and their intersection will be used as the O origin (zero point) for further geometric constructions.[45]
2. Mark the positions of the heel position ($A \rightarrow OA=LP7$)[46], heel centre ($B \rightarrow OB=LP1$), shank centre ($C \rightarrow OC=LP2$), the outer and inner ball position ($D \rightarrow OD=LP3$ and $E \rightarrow OE=LP4$ respectively), the width of small (5th) toe ($F \rightarrow OF=LP6\text{-}7$), the width of the big (1st) toe ($G \rightarrow OG=0.9*L1$) and the foot length ($H \rightarrow OH=L1$), whereas LPi are the measurements taken from feet (i.e. no transformation is needed).
3. Add the toe allowance for growth and toe shape ($J \rightarrow HJ=l_g+\Delta l_a$).
4. Draw perpendiculars to the longitudinal (x) axis at the marked points $B...H$ as indicated on *Figure VI-1.*
5. Mark points on these lines as follows:
   a) the heel width of the bottom pattern is 5% less than that of the foot: this should be equally divided between the inner and outer sides ($BB_1=BB_2=0.45*W1$);
   b) the width of the outer side of the shank ($CC_2=0.8*W2$),[47] but this point is only for orientation;
   c) the outer (D_2) and inner (E_1) ball points determining the ball width ($W7$ and $W8=W3+W4$) which is not divided equally between the inner and outer sides ($DD_2=0.45*W3$ and $EE_1=0.45*W4$).
6. Draw the tangent of the small (5th) and big (1st) toes by constructing the respective angles $B5$ and $B6$ at points D and E: mark intersections with perpendiculars originating at points F and G as F_2 and G_1.
7. Construct the axis of symmetry (CD_3) of the heel part: measure the distance EE_1 from point D_2 inward and mark it as D_3 then connect it with the heel centre C.
8. Find the centre of the heel circle by measuring the half heel width of the bottom pattern (the distance of CC_1 or CC_2) from point B on the axis of symmetry of the heel part and mark it as B_3, then draw a circle using the same radius.
9. Construct the (indicative) front line of the heel:[48] measure ¼ of the foot length from the origin O on the axis of symmetry of the heel and mark the point as B_4 ($OB_4=0.25*L1$), then draw a perpendicular to the axis of symmetry;
10. To facilitate the construction of the inner part of the shank line[49] draw lines E_1B_2 and C_2D_3.
11. Finally connect points B_2, C_2, D_2, F_2, J, G_1, E_1 and B_1 with a smooth curve as shown on *Figure VI-2* so that
    a) the line joins smoothly the heel circle;
    b) the shape of the toe part follows the actual fashion trend (when it is calling for a narrow shape there may be need to increase the Δl_a shape allowance[50] as the contour of the bottom pattern should pass through points F_2 and G_1 - or anywhere outside - otherwise the shoe may cause serious damages to the wearer's feet (it is especially dangerous in case of children).

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[44]Normally the right pattern is constructed (that is why right feet were measured in the process of the foot survey).

[45]As an old convention the longitudinal axis (x) is drawn vertically and the width axis (y) horizontally -just the reverse of the widely used mathematical notation.

[46]In case of the recent foot survey made in India the results were rather unreliable therefor it is recommended to use the Δl_{hp} values indicated in *Table VI-1.*

[47]The coefficient may be in the range of 0.7÷0.9 depending on heel height and shank shape of the (out)sole.

[48]The heel is supposed to cover the last bottom (or insole) up to this front line. The backpart of the shoe last bottom pattern ought to be symmetric up to this front line; this enables the shoe manufacturers to use uniform heel (without distinguishing lefts and rights).

[49]This line may not be felt or seen on the surface of the last (especially in case of high heels) but the line is needed for production of components such as insoles, shanks and soles, as well as for cutting shoe last bottom plates.

[50]In extreme cases it may be as much as 30÷40 mm for adult footwear).

Using this method (algorithm) and data derived from the recent foot syrvey made in India shoe last bottom patterns were constructed for all five size groups: they are attached as *Annex K*.

The bottom pattern should be cut from cardboard, plastic or metal sheet. It is then used for constructing patterns for components such as insoles, heels, shanks, outsoles and (or) for the cavity of corresponding moulds. The bottom pattern is also used for quality control and shoe size grading.

The shoe last is normally made from a block or a larger last using traditional method, whereby the bottom pattem is used extensively to check the volume of the bottom part of the last. When the sample last is ready, checked and accepted, then the longitudinal section shape and one or more cross sections (especially at the heel part) are taken from the last and the corresponding patterns are prepared.

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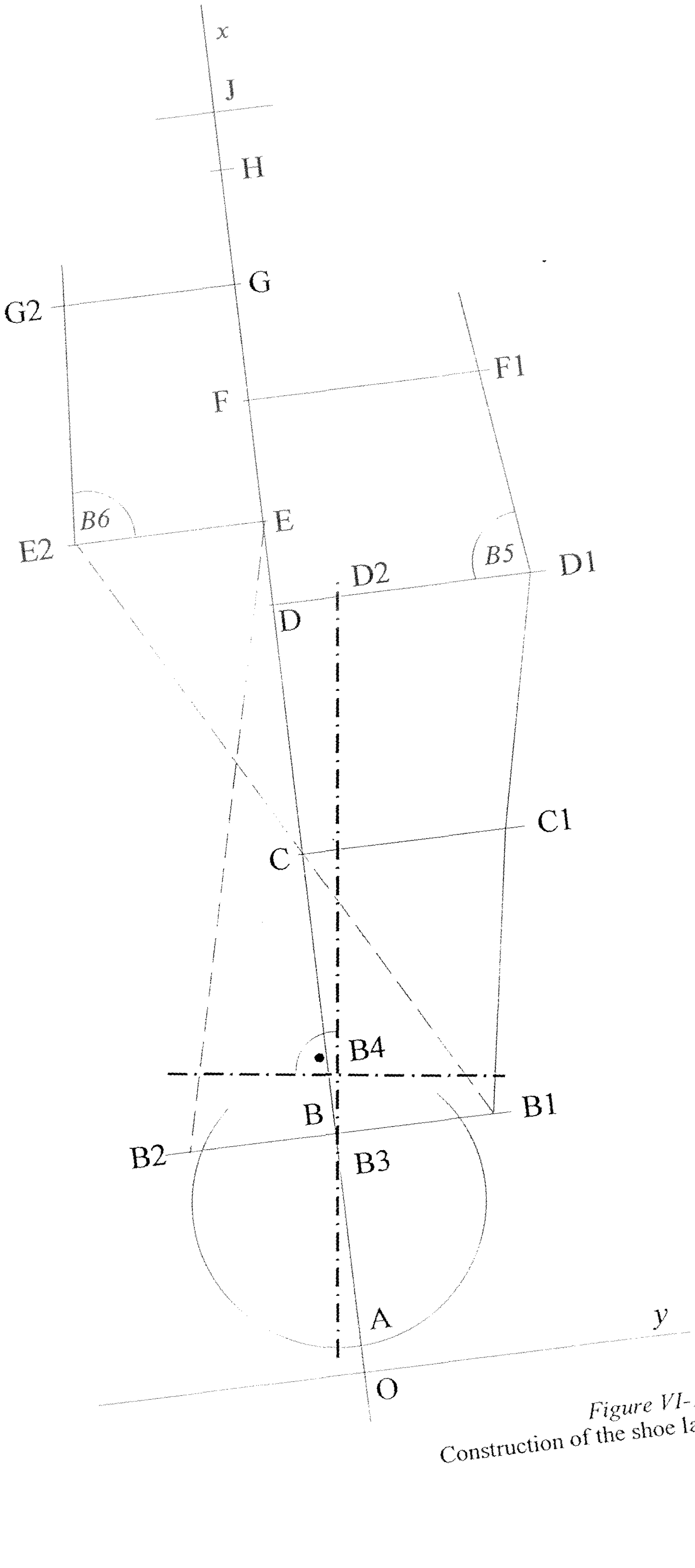

Figure VI-1.
Construction of the shoe last bottom pattern

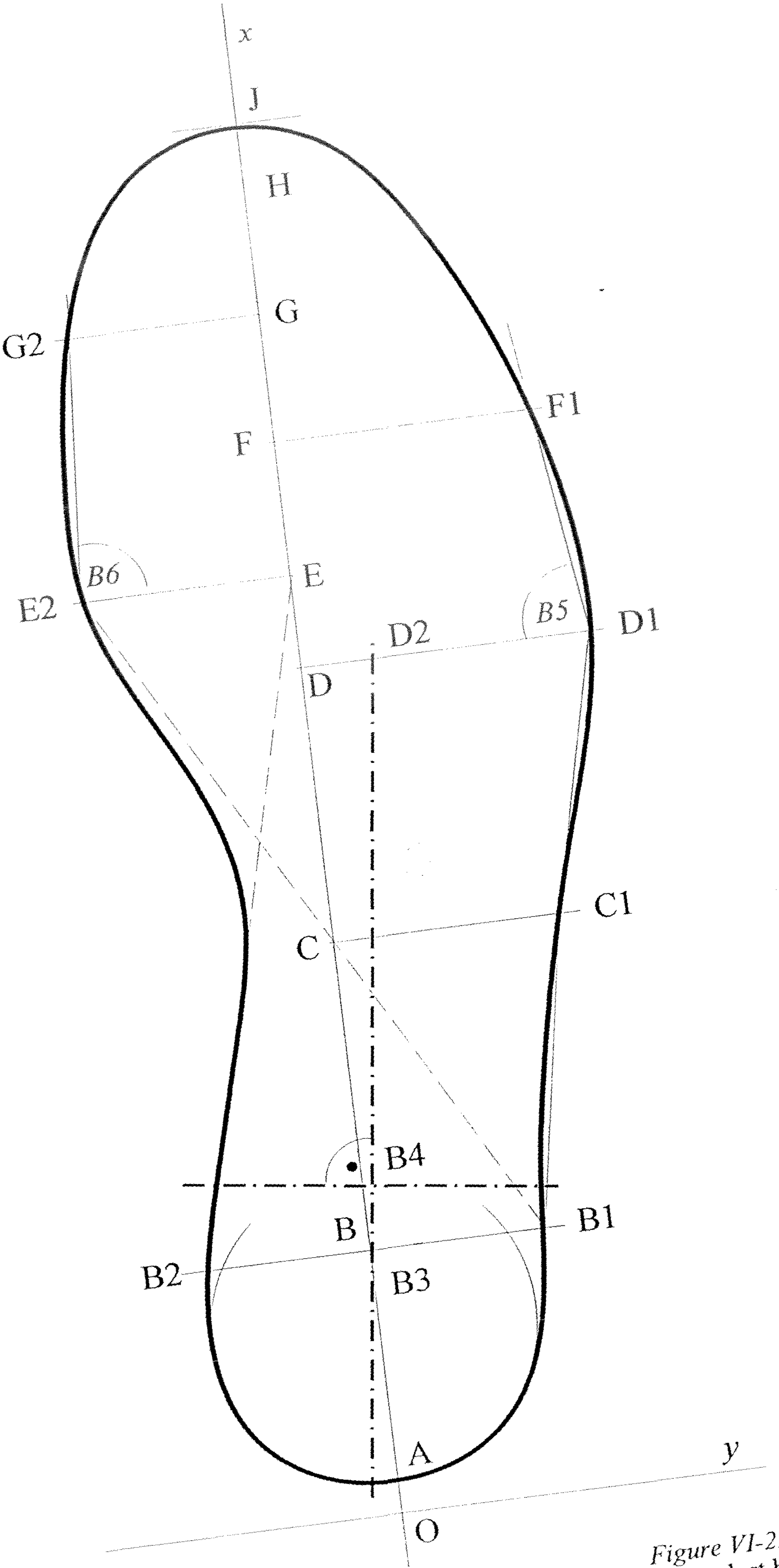

Figure VI-2.
Countur of the shoe last bottom pattern

Annexes

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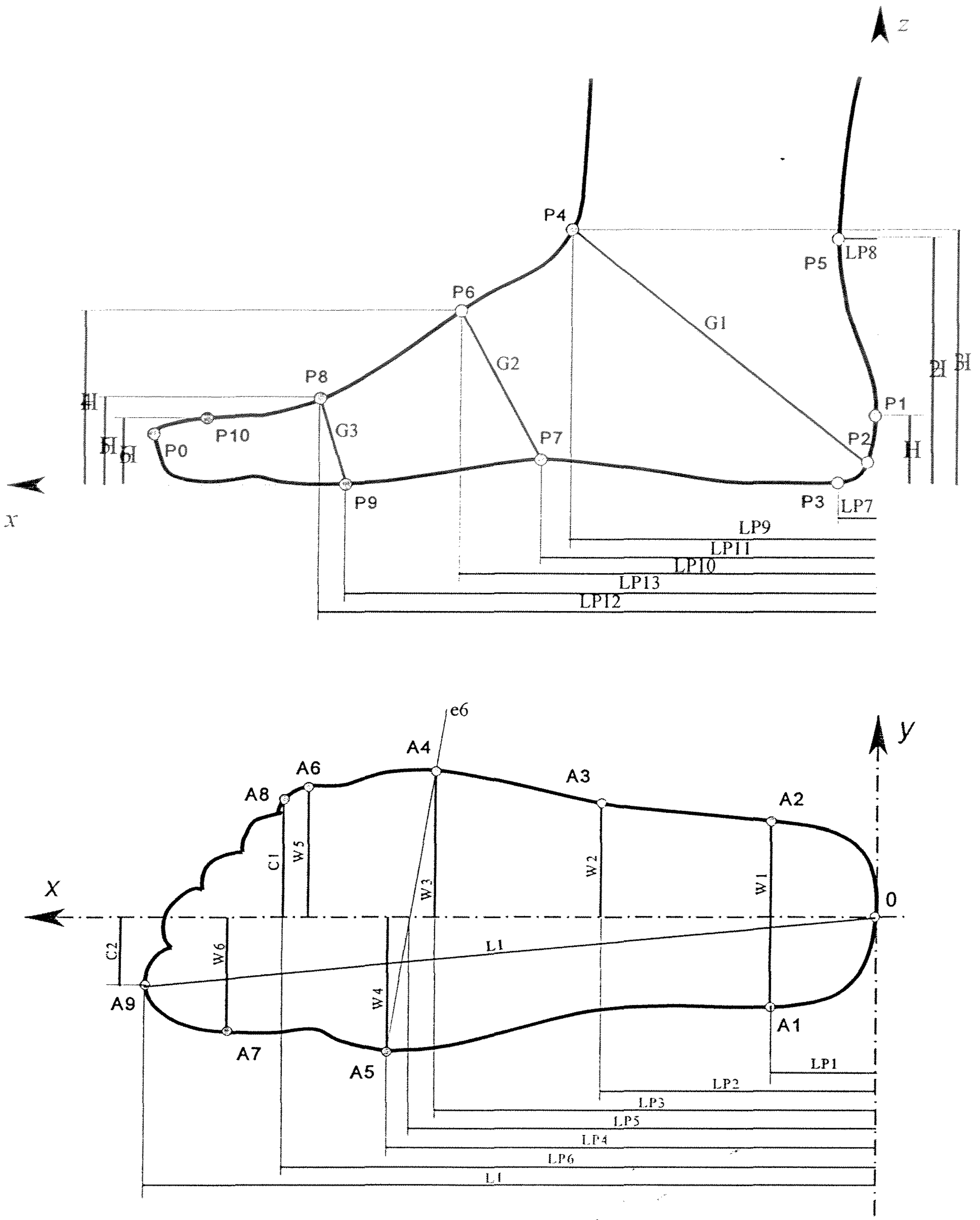

Figure A-1. Measuring points on side and bottom (plantar) views

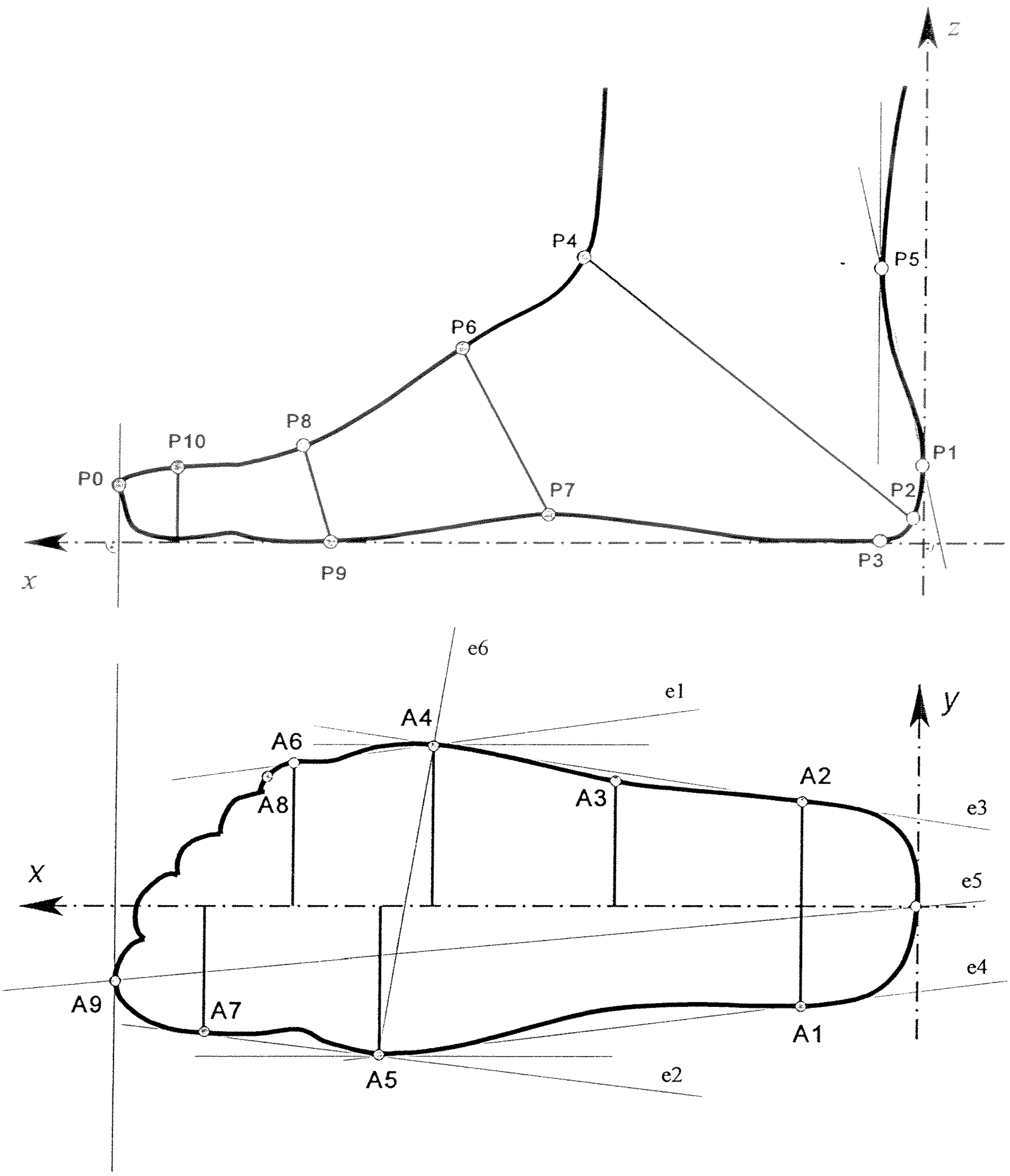

Figure A-2. Characteristic lines on sise and bottom viws

Annex B

VARIABLES OF MEASUREMENT AND CALCULATION PROCEDURES

Conventions: x(), y(), z() = *x*, *y* or *z* coordinate of a point
d(,) = distance between two points
e(,) = straight line passing determined by two (not coinciding) points
α(,) = angle between two intersecting straight lines

Foot lengths:

L1	projective	x(A9)
L2	dimensional	d(O,A9)

Foot sizes:

EN	length in Enflish size units	L1/8.46
EN_HALF_0	length in English half sizes	iif(mod(10*EN,10)<=5,int(EN)+0.5,int(EN)+1)
EN_INT_0	length in English full sizes	iif(EN=int(EN),EN,EN+1)
EN_GR	English size group	iif(EN<=25,1,2)
EN_HALF	English half size	iif(EN<25,EN_HALF_0-12,EN_HALF_0-25)
EN_INT	English full size	round(EN_HALF,0)
FR	size in French points	int(0.15*L1)+1

Widths:

W1	heel	d(A1,A2)
W2	outer shank	y(A3)
W3	outer ball	y(A4)
W4	inner ball	y(A5)
W5	small toe	y(A6)
W6	big toe	y(A7)
W7	ball dimensions	d(A4,A5)
W8	ball projections	abs(y(A4)+y(A5))

Excentricities:

C1	big toe	y(A9)
C2	small toe	y(A8)

Longitudinal positions:

LP1	heel point	(x(A1)+x(A2))/2
LP2	shank point	x(A3)
LP3	outer ball point	x(A4)
LP4	inner ball point	x(A5)
LP5	ball part centrum	(x(A4)+x(A5))/2
LP6	small toe	x(A8)
LP7	heel point	x(P3)
LP8	ankle curve	x(P5)
LP9	instep	x(P4)
LP10	upper waist	x(P6)

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LP11	lower waist	x(P7)
LP12	upper ball	x(P8)
LP13	lower ball	x(P9)

Heights:

H1	heel curve	z(P1)
H2	ankle curve	z(P5)
H3	instep	z(P4)
H4	waist	z(P6)
H5	ball	z(P8)
H6	big toe	z(P10)

Girth (perimeter) projections:

G1	instep	d(P2,P4)
G2	waist	d(P6,P7)
G3	ball	d(P8,P9)

Angles:

B1	heel width	α(e(A1,A2),x)
B2	ball width	α(e(A4,A5),x)
B3	outer part	90°-α(e3,x)
B4	inner part	90°-α(e4,x)
B5	small toe	90°-α(e1,x)
B6	bid toe	90°-α(e2,x)
B7	heel part	α(e3,e4)
B8	instep	α(e(P2,P4),x)
B9	waist	α(e(P6,P7),x)
B10	ball height	α(e(P8,P9),x)
B1	heel curve	α(e(p1,P5),z)

Proportions:

R1	heel centre	(x(A1)+x(A2))/(2*x(A9))
R2	shank point	x(A3)/x(A9)
R3	outer ball point	x(A4)/x(A9)
R4	ball part centre	(x(A4)+x(A5))/(2*x(A9))
R5	inner ball point	x(A5)/x(A9)
R6	small toe width	x(A6)/x(A9)
R7	big toe width	x(A7)/x(A9)
R8	small toe "length"	x(A8)/x(A9)
R9	heel point	x(P3)/x(A9)
R10	ankle curve	x(P5)/x(A9)
R11	instep	x(P4)/x(A9)
R12	waist	x(P6)/x(A9)
R13	upper ball point	x(P8)/x(A9)
R14	heel back point	z(P1)/d(A4,A5)
R15	heel girth projection	d(P2,P4)/d(A4,A5)
R16	waist girth projection	d(P6,P7)/d(A4,A5)
R17	ball girth projection	d(P8,P9)/d(A4,A5)
R18	big toe height	z(P10)/d(A4,A5)
R19	ankle curve point	z(P5)/d(A4,A5)

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Girths (perimeters):

BALLGIRT	ball
HEELGIRT	heel
ANKLEGIR	ankle
ABOVEANK	above ankle (at quarter height)

Personal data and characteristics:

REGION	geographic region: ***N***orth, ***W***est, ***S***outh, ***E***ast
AGE	age [year]
SEX	sex: ***F***emale, ***M***ale
HEIGHT	body height [cm]
WEIGHT	weight [kg]
PROFESSI	profession
MODE	most frequent position at work/daytime
INCOME	income category
EDUCATIO	education level
INCODE	the identifier barcode
PAIRS	shoe consumption [pairs]
ANNUAL	annual expenditures on footwear
CREATDAT	date of data processing

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Annex C

Structure of Databases used in the Survey

DATA1.DBF: **Foot-related data**

Field	*Field name*	*Type*	*Width*	*Dec*	*Start*	*End*
1	CODE	Character	13	0	1	13
2	AGE	Numeric	2	0	14	15
3	SEX	Character	1	0	16	16
4	HEIGHT	Numeric	3	0	17	19
5	WEIGHT	Numeric	3	0	20	22
6	BALLGIRTH	Numeric	3	0	23	25
7	HEELGIRTH	Numeric	3	0	26	28
8	ANKLEGIRT	Numeric	3	0	29	31
9	ABOVEANKL	Numeric	3	0	32	34
10	ABOVEANKL	Numeric	3	0	35	37
	Total length:		38			
	The associated index file is:		DATA1.IDX (*key:* CODE)			

DATA2.DBF: **Personality-related data**

Field	*Field name*	*Type*	*Width*	*Dec*	*Start*	*End*
1	CODE	Character	13	0	1	13
2	PROFESSION	Numeric	3	0	14	16
3	MODE	Numeric	3	0	17	19
4	LOCATION	Numeric	3	0	20	22
5	EDUCATION	Numeric	3	0	23	25
6	INCOME	Numeric	3	0	26	28
7	PAIRS	Numeric	2	0	29	30
8	ANNUAL	Numeric	4	0	31	34
9	OCCASION	Numeric	3	0	35	37
	Total length:		38			
	The associated index file is:		DATA2.IDX (*key:* CODE)			

DATA3.DBF: **Body-related data**

Field	*Field name*	*Type*	*Width*	*Dec*	*Start*	*End*
1	CODE	Character	13	0	1	13
2	CHEST	Numeric	3	0	14	16
3	SEAT	Numeric	3	0	17	19
4	WAIST	Numeric	3	0	20	22
5	NATURAL	Numeric	3	0	23	25
6	NECK	Numeric	3	0	26	28
7	SLEEVE	Numeric	3	0	29	31
8	CLOSE	Numeric	3	0	32	34
	Total length:		35			
	The associated index file is:		DATA3.IDX (*key:* CODE)			

PROFESSI.DBF

Field	Field name	Type	Width	Dec	Start	End
1	CODE	Numeric	3	0	1	3
2	PROFESSION	Character	30	0	4	33
	Total length:		34			

WORKING.DBF

Field	Field name	Type	Width	Dec	Start	End
1	CODE	Numeric	3	0	1	3
2	WORKING	Character	30	0	4	33
	Total length:		34			

LOCATION.DBF

Field	Field name	Type	Width	Dec	Start	End
1	CODE	Numeric	3	0	1	3
2	LOCATION	Character	30	0	4	33
	Total length:		34			

EDUCATIO.DBF

Field	Field name	Type	Width	Dec	Start	End
1	CODE	Numeric	3	0	1	3
2	EDUCATION	Character	30	0	4	33
	Total length:		34			

SEGIT.DBF: **Error messages** of program FootDat

Field	Field name	Type	Width	Dec	Start	End
1	TOPIC	Character	30	0	1	30
2	DETAILS	Memo	10	0	31	40
3	CLASS	Character	20	0	41	60
	Total length:		61			

SETUP.DBF: **Installation and operational parameters** of FootDat

Field	Field name	Type	Width	Dec	Start	End
1	UTVONAL	Character	60	0	1	60
2	MONITOR	Numeric	1	0	61	61
3	PRINTINIT	Character	60	0	62	121
4	PRINTEND	Character	60	0	122	181
5	INDITO	Numeric	1	0	182	182
6	AUTOINDEX	Logical	1	0	183	183
	Total length:		184			

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DATAx.DBF

Field	Field Name	Type	Dec	Width
1	Bbarcode	Character	0	13
2	Sbarcode	Character	0	13
3	Creatdate	Date	0	8
4	Procdate	Date	2	8
5	L1	Float	2	12
6	L2	Float	2	12
7	W1	Float	2	12
8	W2	Float	2	12
9	W3	Float	2	12
10	W4	Float	2	12
11	W5	Float	2	12
12	W6	Float	2	12
13	C1	Float	2	12
14	C2	Float	2	12
15	LP1	Float	2	12
16	LP2	Float	2	12
17	LP3	Float	2	12
18	LP4	Float	2	12
19	LP5	Float	2	12
20	LP6	Float	2	12
21	LP7	Float	2	12
22	LP8	Float	2	12
23	LP9	Float	2	12
24	LP10	Float	2	12
25	LP11	Float	2	12
26	LP12	Float	2	12
27	LP13	Float	2	12
28	H1	Float	2	12
29	H2	Float	2	12
30	H3	Float	2	12
31	H4	Float	2	12
32	H5	Float	2	12
33	H6	Float	2	12
34	G1	Float	2	12
35	G2	Float	2	12
36	G3	Float	2	12
37	B1	Float	2	12
38	B2	Float	2	12
39	B3	Float	2	12
40	B4	Float	2	12
41	B5	Float	2	12
42	B6	Float	2	12
43	B7	Float	2	12
44	B8	Float	2	12
45	B9	Float	2	12
46	B10	Float	2	12
47	B11	Float	2	12
48	R1	Float	2	12
49	R2	Float	2	12
50	R3	Float	2	12
51	R4	Float	2	12
52	R5	Float	2	12
53	R6	Float	2	12
54	R7	Float	2	12
55	R8	Float	2	12
56	R9	Float	2	12
57	R10	Float	2	12
58	R11	Float	2	12
59	R12	Float	2	12
60	R13	Float	2	12
61	R14	Float	2	12
62	R15	Float	2	12
63	R16	Float	2	12
64	R17	Float	2	12
65	R18	Float	2	12
66	R19	Float	2	12
Total length				*787*

DALL.DBF: **Merged database**

Field	FieldName	Type	Dec	Width
1	CODE	C	0	13
2	SBARCODE	C	0	13
3	REGION	C	0	1
4	CREATDATE	D	0	8
5	PROCDATE	D	0	8
6	L1	N	2	12
7	L2	N	2	12
8	W1	N	2	12
9	W2	N	2	12
10	W3	N	2	12
11	W4	N	2	12
12	W5	N	2	12
13	W6	N	2	12
14	C1	N	2	12
15	C2	N	2	12
16	LP1	N	2	12

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Field	*FieldName*	*Type*	*Dec*	*Width*
17	LP2	N	2	12
18	LP3	N	2	12
19	LP4	N	2	12
20	LP5	N	2	12
21	LP6	N	2	12
22	LP7	N	2	12
23	LP8	N	2	12
24	LP9	N	2	12
25	LP10	N	2	12
26	LP11	N	2	12
27	LP12	N	2	12
28	LP13	N	2	12
29	H1	N	2	12
30	H2	N	2	12
31	H3	N	2	12
32	H4	N	2	12
33	H5	N	2	12
34	H6	N	2	12
35	G1	N	2	12
36	G2	N	2	12
37	G3	N	2	12
38	B1	N	2	12
39	B2	N	2	12
40	B3	N	2	12
41	B4	N	2	12
42	B5	N	2	12
43	B6	N	2	12
44	B7	N	2	12
45	B8	N	2	12
46	B9	N	2	12
47	B10	N	2	12
48	B11	N	2	12
49	R1	N	2	12
50	R2	N	2	12
51	R3	N	2	12
52	R4	N	2	12

Field	*FieldName*	*Type*	*Dec*	*Width*
53	R5	N	2	12
54	R6	N	2	12
55	R7	N	2	12
56	R8	N	2	12
57	R9	N	2	12
58	R10	N	2	12
59	R11	N	2	12
60	R12	N	2	12
61	R13	N	2	12
62	R14	N	2	12
63	R15	N	2	12
64	R16	N	2	12
65	R17	N	2	12
66	R18	N	2	12
67	R19	N	2	12
68	AGE	N	2	
69	SEX	C	1	
70	HEIGHT	N	3	
71	WEIGHT	N	3	
72	BALLGIRTH	N	3	
73	HEELGIRTH	N	3	
74	ANKLEGIRTH	N	3	
75	ABOVEANKLG		N	3
76	ABOVEANKLH		N	3
77	PROFESSION	N	3	
78	MODE	N	3	
79	INCOME	N	3	
80	EDUCATION	N	3	
81	INCODE	N	3	
82	PAIRS	N	2	
83	ANNUAL	N	4	
84	OCCASION	N	3	

Total Length: *836*

Number of data records: 3383

*Annex **D***

FMS-II Technical Reference Manual

D.1. General Description

The *Foot Measurement System* (FMS-II) is a computerized equipment of precise and quick data capture from human foot. Its speed assigns it to be a powerful tool for mass sampling surveys preparing regional standards of shoe industry.

The system consist of the following parts:

- Universal Power Supply Unit (UPS)
- Computerized Data Processing Unit (DPU)
- Computerized Image Processing Unit (IPU)
- Optical Foot Measurement Unit (FMU)
- Control Unit (CU)

D.2. The Universal Power Supply

The *Universal Power Supply (UPS)* as shown on *Figure D-1* is a standby uninterruptible power source that supplies appropriate electric power for all the components of the FMS-II.

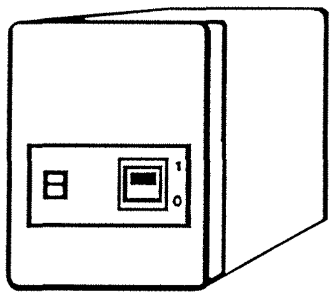

Figure D-1. UPS

In the event of a utility failure such as a blackout, brownout or sag, the UPS rapidly transfers loads (computer and other equipment) plugged in as its output to an alternative power source. This alternative power is derived from a battery within the UPS and provides the user with ample time to save file data and close operations (sampling procedure, etc). Normally, when the utility voltage is within limits which are safe for the equipment, the UPS maintains the battery in a charged condition and serves to isolate the equipment from surges and EMI/RFI noise brought from the utility.

D.2.1. Controls and Indicators

Power I/O switch

The power I/O switch controls power to the UPS and its output receptacles. When the switch is on, the UPS operates and the computer (or other) equipment will be powered. When the switch is off, the UPS is de–energized and the equipment is un-powered. Leaving all the equipments' power switches in ON state, the entire system can be operated by using the power I/O switch. The lamp within the power I/O switch illuminates whenever normal voltages are present at the output receptacles. This means that the lamp will be extinguished when the UPS shuts down due to overloads or low battery conditions.

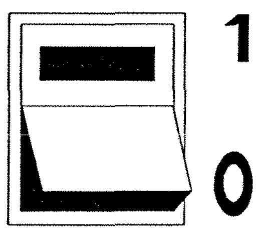

Figure D-2.

Test/Alarm Disable switch

When operating during a utility power failure, the UPS will emit a beep once every five seconds. This beep can be silenced by pressing the alarm disable control. However, the UPS low battery warning will still sound in the event of an extended utility outage. When the *Test* portion of the Test/alarm disable switch is pressed, the UPS simulates a power outage and transfers the load to the alternate power source. This feature allows to determine that computer (and/or other) equipment protected by the UPS operates normally during transfers. It also provides a convenient means of testing the UPS's battery. If the *Test* control is held depressed, the UPS will operate the connected from power derived from the battery continuously. If during the test the low battery warning is sounded prematurely and the load is known to be normal, then the battery is weak and requires extended recharge or replacement.

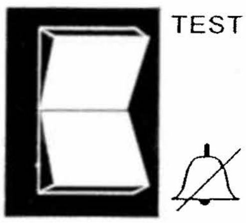

Figure D-3.

Audible alarm

During a utility failure, the UPS emits a beep once every five seconds to warn the user that the connected equipment is operating from a source of power which is limited in duration. The alarm can be defeated using the alarm disable switch. In the event of an extended utility failure, the UPS will sound a loud tone 2 minutes in advance of shut down due to battery capacity exhaustion. Once shut down, the UPS will return to the periodic beep. The UPS should be turned off at this point to cease the alarm. In the event the UPS encounters a severe overload, the UPS will shut down and emit a loud tone The alarm is reset when the UPS is turned off.

D.2.2. Technical Characteristics

Input

Nominal input voltage:	single phase, 230 VAC
Nominal input frequency:	50 Hz

Transfer Characteristics

Frequency limits for operation from utility:	50 Hz, ± 5%
Low input voltage limit for operation from utility:	197 VAC, may be set lower
Transfer time:	3 ms typical, 4 ms maximum

Output Characteristics

Nominal output voltage:	225 VAC, ± 5%
Maximum load capacity:	600 VA or 400 W
Frequency:	50 Hz ± 3 % unless synchronized to the utility
Waveshape:	stepped approximation to sine wave; peak & rms values equivalent to utility
Protection:	electronically over current, short circuit protected, latched shut down upon overload

Battery and Charger

Battery type:	maintenance–free lead–acid, sealed and leak-proof
Typical service life:	3–6 years, dependent on number of discharge cycles, temperature

Low battery signaling:	audible tone, computer interface output, selectable 2 or 5 minute
Recharge time:	6 to 10 hours, dependent on load and length of utility outage

Surge and Noise Suppression

Surge energy rating:	320 Joules (one time, 10/1000 μs waveform)
Surge current capability:	6500 Amp peak (one time, 8/20 μs waveform)
Surge response time:	0 ns (instantaneous) normal mode, <5 ns common mode
Noise filter:	full time EMI/RFI suppression, 100 KHz to 10 MHz

Operating Environment

Temperature:	0°C to 40°C (32°F to 104°F)

Physical

Size:	6.6" H x 4.7" W x 14.2" D (17 cm x 12 cm x 36 cm)
Weight:	25 lb (11.3 kg)

D.2.3. Structure of UPS

Figure D-4 shows the major components of the Universal Power Supply. These blocks are referred with a number, the legend can be seen below.

1. Noise and surge suppression
2. Load transfer switch
3. Battery charger
4. Battery
5. Inverter
6. Transformer
7. Monitoring and control electronics

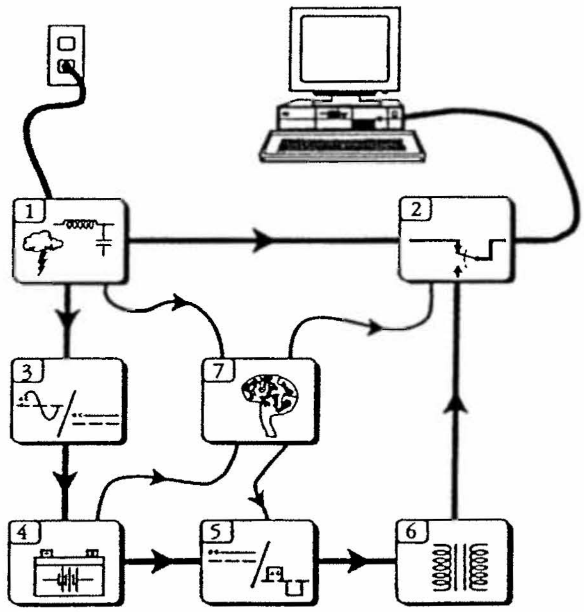

Figure D-4. Block Diagram of UPS

D.3. Computerized Data Processing Unit

This unit stores and processes the respondents' personal data.

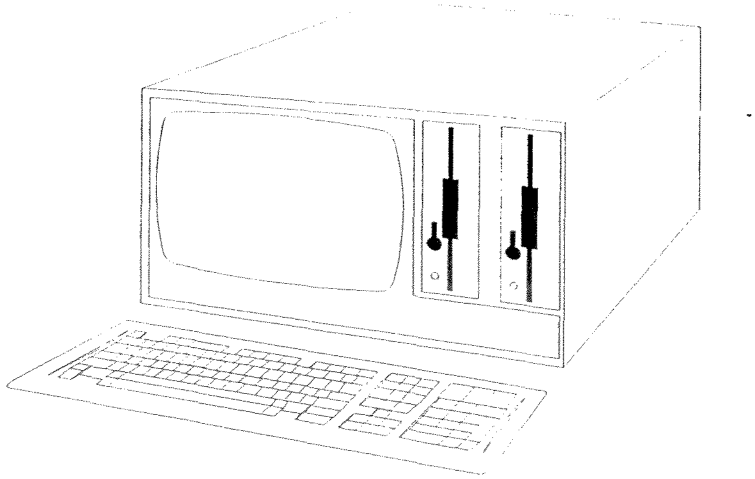

Figure D-5. External view of DPU

D.3.1. Portable Computer

Display

Display size (diagonal):	9"
Display dot pitches:	0.26
Internal and external max resolution:	1024 * 768
Shades/color:	unlimited

Display Adapter

Video RAM:	1 MB
Chip set:	ET4000

Power Supply

For the computer:	200 Watt
For display:	65 Watt
220/110 V selecting:	automatic

Chassis

Motherboard platform:	standard baby AT size
Internal chassis:	light weight aluminum
Drives bays:	two 5.25" open framed and one 3.5" internal
Slots position:	three AT full length and two AT half length

Keyboard

101/102 keys removable with standard DIN connection

Physical

Size:	8.2" H x 16" D x 16" W
Weight:	25 lbs.

Environment

FCC Class B (Systems):	yes
UL/TÜV:	yes
CSA (OEM only):	OEM only
Operating temperature:	10°C ÷ 45°C
Storage temperature:	–10°C ÷ 60°C

D.3.2. Main Board

Technical Characteristics

Type:	ALI 386SX
CPU:	Intel/AMD 80386SX
System memory size:	1 Mbyte
Number of interrupt levels:	15
BIOS manufacturer:	AM

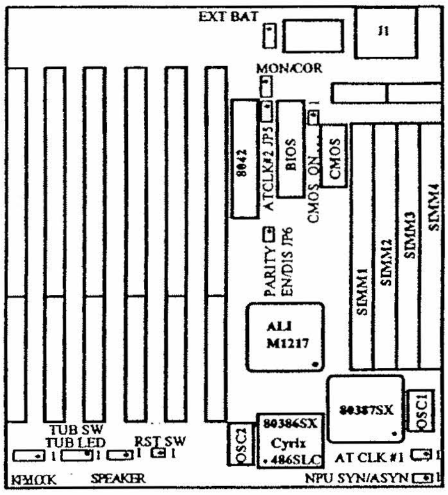

Figure D-6. Physical layout

D.3.3. Bar Code Interface

The *Barcode Interface Unit (BIU)* used to read the unique bar codes identifying the persons involved into measurement survey. Replaces the keyboard input and eliminates the typing errors.

Technical Characteristics

Type:	CCD 63
Sensor:	CCD Photo sensor
Light Source:	660 nm Red LED
Resolution:	2048 pixels
Power supply:	+5 V +/- 5%
Power consumption:	120 mA
Scan rate:	40/sec
Reading width:	80 mm max.
Code type:	EAN-13
Emulation:	Keyboard

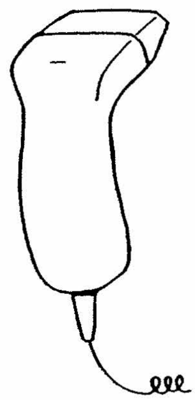

Figure D-7. BIU

Barcode Characteristics

Type:	EAN-13
Length:	13 Digits (12 + 1)

Figure D-8. EAN-13 Barcode

D.4. Computerized Image Processing Unit

The *Image Processing Unit (IPU)* handles and stores the pixel graphical image data received from the video cameras of the *Foot Measurement Unit (FMU)*. Since this procedure requires big CPU power and very large disk spaces, this unit contains a fast IBM–compatible computer with special extensions for the image processing (video digitizer card, special driver software).

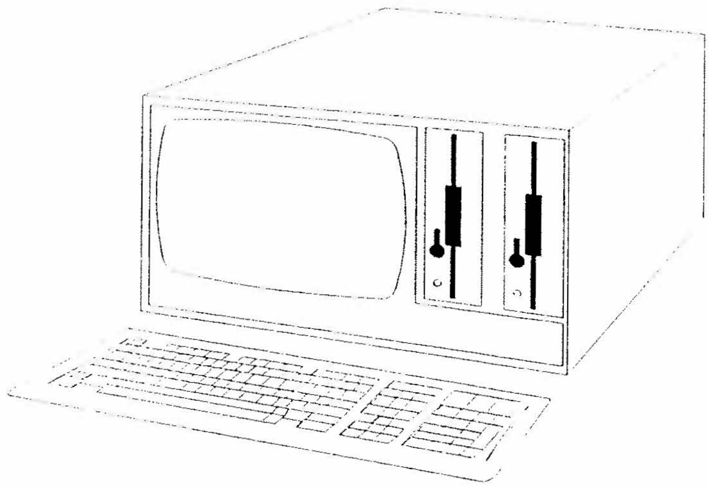

Figure D-9. External view of IPU

D.4.1. Portable Computer

Display

Display size (diagonal):	9"
Display dot pitches:	0.26
Internal and external max resolution:	1024 * 768
Shades/color:	unlimited

Display Adapter

Video RAM:	1 MB
Chip set:	ET4000

Power Supply

For the computer:	200 Watt
For display:	65 Watt
220/110 V selecting:	automatic

Chassis

Motherboard platform:	standard baby AT size
Internal chassis:	light weight aluminum
Drives bays:	two 5.25" open framed and one 3.5" internal
Slots position:	three AT full length and two AT half length

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Keyboard

101/102 keys removable with standard DIN connection

Physical

Size:	8.2" H x 16" D x 16" W
Weight:	25 lbs.

Environment

FCC Class B (Systems):	yes
UL/TÜV:	yes
CSA (OEM only):	OEM only
Operating temperature:	10°C ÷ 45°C
Storage temperature:	–10°C ÷ 60°C

D.4.2. Main Board

Type:	G386UH
CPU:	Intel/AMD 80386–DX–40/33 micro–processor runs at 40/33 MHZ speed
Cache memory size:	64 Kbytes
System memory size:	4 Mbytes
Number of DMA channels:	7
Number of interrupt levels:	15
BIOS manufacturer:	AMI

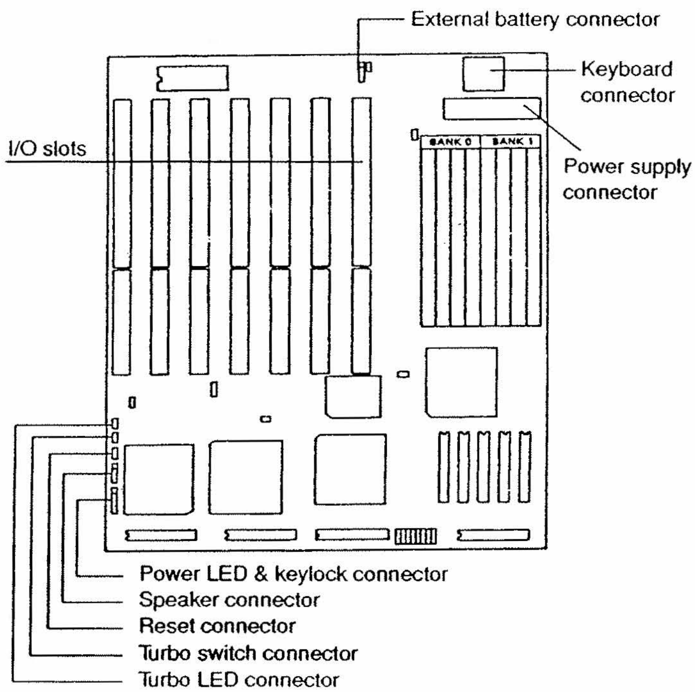

Figure D-10. Physical layout

D.4.3. Bar Code Interface

The *Barcode Interface Unit* used to read the unique bar codes identifying the persons involved into measurement survey. Replaces the keyboard input and eliminates the typing errors.

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Technical Characteristics

Type:	CCD 63
Sensor:	CCD Photo sensor
Light Source:	660 nm Red LED
Resolution:	2048 pixels
Power supply:	+5 V +/- 5%
Power consumption:	120 mA
Scan rate:	40/sec
Reading width:	80 mm max.
Code type:	EAN-13
Emulation:	Keyboard

D.4.4. Streamer Tape Backup Unit

The *Streamer Tape Backup Unit (STBU)* provides on capability of mass data storage. After digitizing and compressing the pictures made by FMU, the picture files have to be stored for a long time. Although the computer's hard drive capacity is very limited. Thus the actual data will be cleared from IPU's hard drive by writing them onto streamer tape.

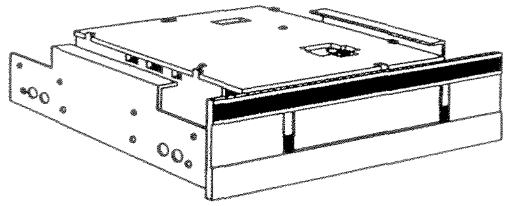

Figure D-11. External view of the STBU

Technical Characteristics

Type:	Colorado Jumbo 250
Capacity:	250 Mb
Cartridge:	307 ft DC2120
Tape Format:	QIC-80/28 trk/14.700 FRPI
Power supply:	12V 0.8A / 5V 0.3A
Power consumption:	11.5 W
Transfer Rate:	1 Mb/s
Communications:	QIC-117 Command Set
RAM required:	512KB

D.5. Optical Foot Measurement Unit

D.5.1. Structure

The FMU is the most important unit in the chain of the sampling system. It captures (with the two built–in video–cameras) video images and sends video signals trough the Control Unit (CU) to the IPU. The video cameras require special colored lights to receive the proper picture quality. That is why the FMU contains a pair of strong light sources, for both (bottom and side) views.

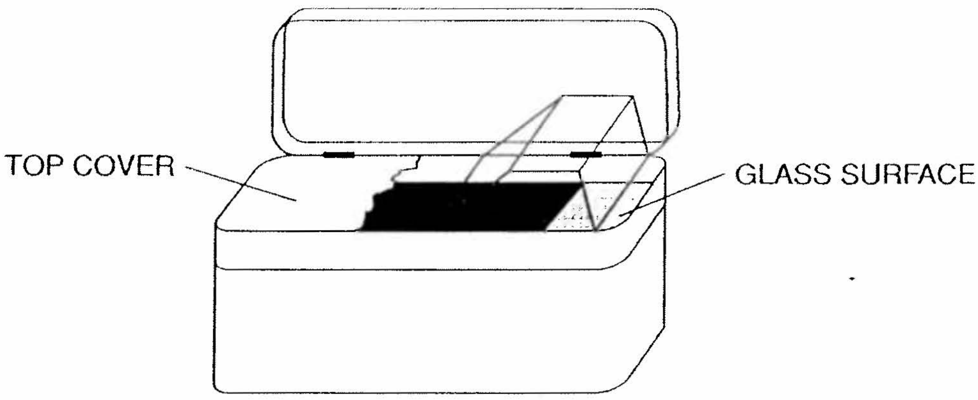

Figure D-12. External view of FMU

These light sources are halogen lamps, with special, yellow-colored glass filters. There are two spot lamps for both directions, i.e one pair for the bottom camera and one pair for side camera. The light sources are digitally controllable from the IPU computer's FootGrab software within 16 grades of intensity. This software automatically switches the light sources when changing the cameras, i.e. when changing the video sources. Finishing the daily sampling procedure the software stores the currently used camera and light settings in disk files.

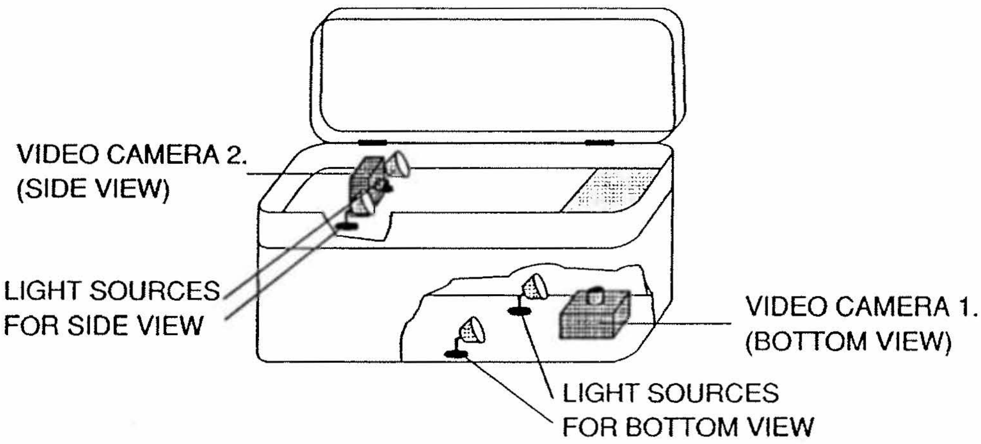

Figure D-13. Position of video cameras in FMU

D.5.2. Halogen Lamps

Technical Characteristics

Type:	Halopika
Manufacturer:	PEC Phoenix Electronics Co. \ Japan
Subtype:	Projector lamp BAB
Glass Type:	Frontglass
Glass Color:	Yellow
Power Requirement:	12 V DC\ 20 W
Connector Type:	2-Pin

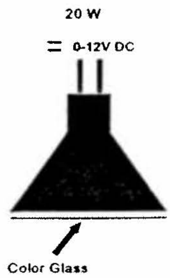

Figure D-14.

D.5.3. Digital Cameras

Technical Characteristics

Type:	MTV-231CM
Manufacturer:	Mintron Enterprises / Taiwan
Image Sensor Device:	1/3 inch interline transfer CCD
Image Sensor Area:	4.9 mm (H) * 3.7 mm (V)
Picture elements:	542 (H) * 582 (V)
Horizontal frequency:	15.625 KHz
Vertical frequency:	50 Hz
Lens:	f=3.6 mm, F=2.8
Power consumption:	1.8 W

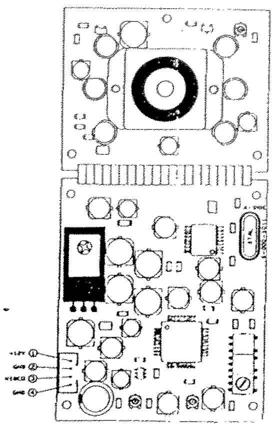

Figure D-15.
Camera Board

D.6. Control Unit

The CU is the controlling and powering unit of the sampling system. Its functions includes to supply the FMU with proper DC current, to control the selection of video sources in FMU, to control the selection of actual pair of halogen lamps in the FMU, to control the digital regulation of brightness and contrast in the FMU and to transfer the video signals from FMU to IPU.

The light sources are digitally controllable from the IPU computer's FootGrab software within 16 grades of intensity. This software automatically switches the light sources when changing the cameras using the CU. The DC power is transformed from the 220V AC source using a standard switching power supply.

All cables connecting the CU with FMU are installed using ground-independent solutions to isolate the FMU from AC high voltages. The digital control is realized by special interface and control printed circuit boards.

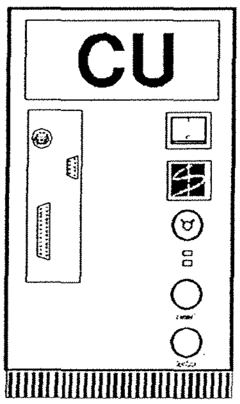

Figure D-16.
External view of CU

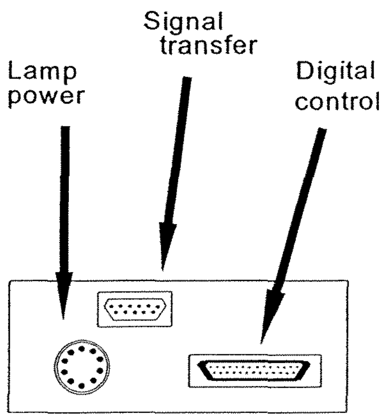

Figure D-17.
The Interface Panel of CU.

There are two independent PCB in the unit. Each PCB controls a pair of halogen lamps. The digital interface physically provides on 4096 level of light intensity but in practical solution only 16 levels are used. By this way the brightness could be regulated precisely in accordance with the contrast level. The PCB is sampling the digitally controlled regulation voltage and transforms it to the appropriate level of DC output power.

D.6.1. Control Functions

Lamp intensity control	
Type:	I/O Digital
Input:	Centronics Printer Port
Resolution:	8 bit/2 * 4 bit/pair of lamps
Input characteristic:	0V ÷ +5V TTL, 16 level
Output characteristic DC 0V - +12V:	Pulse Width Modulation
Camera power control	
Type:	CCIR Analog
Input:	DC 12 V continuous
Output characteristic DC +12V:	400 mA
Video source control	
Type:	Software selection, Digital
Input:	Binary 0/1/2
Output characteristic:	Composite Video signal

D.6.2. Power Functions

Lamp intensity control	
Output PWM max. +12 V:	3.5 A
Fuse:	4 A
Camera power control	
Output DC +12 V:	200 mA
Control unit's own Power Supply	
Type:	PS-200
Input:	110V/220V AC Switchable
Output DC +5V:	20 A
Output DC -5V:	0.5 A
Output DC +12V:	8 A
Output DC -12V:	0.5 A
Fuse:	250V F5A

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y		x	AGE	HEIGHT	WEIGHT	L1	W1	W3	W4	W5	W6	W7	W8	H3	H4	H5	G1	G3	BALLGIRT	ANKLEGIR
			year	cm	kg	mm	mm	mm	mm	mm	mm	mm	mm	mm	mm	mm	mm	mm	mm	mm
HEIGHT	cm	r	0.848																	
		m	5.141																	
		b	76.527																	
WEIGHT	kg	r	0.738	0.857																
		m	2.199	0.421																
		b	4.899	-27.906																
L1	mm	r	0.791	0.893	0.807															
		m	7.700	1.433	2.636															
		b	148.450	38.555	150.637															
L2	mm	r	0.616	0.892	0.807	0.997														
		m		1.422	2.617	0.991														
		b		41.290	152.468	3.408														
LP1	mm	r				0.484														
		m																		
		b																		
LP2	mm	r				0.762														
		m				0.554														
		b				-23.494														
LP3	mm	r				0.841														
		m				0.836														
		b				-37.442														
LP4	mm	r				0.906														
		m				0.743														
		b				-3.568														
LP5	mm	r				0.923														
		m				0.789														
		b				-20.505														
LP6	mm	r				0.943														
		m				0.913														
		b				-14.440														
LP7	mm	r				0.139														
		m																		
		b																		
LP8	mm	r				0.135														
		m																		
		b																		
LP9	mm	r				0.764													0.523	0.013
		m				0.512														
		b				-18.915														
LP10	mm	r				0.829														
		m				0.699														
		b				-17.072														
LP11	mm	r				0.808														
		m				0.320														
		b				16.625														
LP12	mm	r				0.930														
		m				0.834														
		b				-4.826														
LP13	mm	r				0.964														
		m				0.770														
		b				-0.413														
W1	mm	r	0.483	0.604	0.584	0.698						0.690	0.736						0.567	
		m											0.526							
		b											11.759							
W2	mm	r					0.520	0.850				0.409	0.428						0.430	
		m						0.731												
		b						4.565												
W3	mm	r										0.386	0.355						0.440	
		m																		
		b																		
W4	mm	r										0.558	0.621						0.309	
		m																		
		b																		
W5	mm	r										0.227	0.153						0.309	
		m																		
		b																		
W6	mm	r										0.420	0.491						0.130	
		m																		
		b																		
W7	mm	r	0.573	0.690	0.654	0.762							0.960						0.627	
		m				0.311							0.945							
		b				24.568							7.097							
W8	mm	r	0.605	0.715	0.673	0.776						0.960							0.624	
		m		0.477		0.322						0.976								
		b		30.692		20.003						-0.127								
C1	mm	r							0.605		0.665	0.126	0.158							
		m																		
		b																		
C2	mm	r						0.840		0.939		0.119	0.031							
		m						0.966		0.985										
		b						-5.833		-6.128										
H1	mm	r																	0.190	
		m																		
		b																		

y		x	AGE	HEIGHT	WEIGHT	L1	W1	W3	W4	W5	W6	W7	W8	H3	H4	H5	G1	G3	BALLGIRT	ANKLEGIR
			year	cm	kg	mm	mm	mm	mm	mm	mm	mm	mm	mm	mm	mm	mm	mm	mm	mm
H2	mm	r																	0.262	
		m																		
		b																		
H3	mm	r																	0.323	
		m																		
		b																		
H4	mm	r																	0.311	
		m																		
		b																		
H5	mm	r																	0.344	
		m																		
		b																		
H6	mm	r														**0.843**			0.399	
		m														0.765				
		b														1.753				
G1	mm	r												0.370					0.640	
		m																		
		b																		
G2	mm	r													0.345				0.650	
		m																		
		b																		
G3	mm	r														**0.872**			0.382	
		m														0.893				
		b														4.525				
BALLGIRT	mm	r	0.566	0.676	0.633	**0.850**						0.627	0.624					0.382		
		m				0.731														
		b				4.565														
HEELGIRT	mm	r			**0.729**							0.618	0.624				**0.732**		**0.792**	
		m			2.768												1.376		1.162	
		b			178.565												96.419		37.588	
ANKLEGIR	mm	r			0.695							0.558	0.564						0.690	
		m																		
		b																		
ABOVEAN	mm	r			0.663							0.635	0.667						0.486	0.506
		m																		
		b																		

Multiple linear regression Table IV-2.1b

y		x	Coefficients for							
			r	HEIGHT	L1	W7	H5	G3	BALLGIRT	b
BALLGIRT	mm		0.696							
			0.711	0.592		0.594				50.631
			0.628							
			0.632							
			0.635							
W7	mm		0.683							
			0.693							
			0.694							

Remarks: *r* coefficient of linear correlation

Regression equations are in form of y = m x + b

Irrelevant relationship

■ "Selfcorrelation" (r=1)

Bold = strong relation (r>0.7)

Equation parameters are missing for cases of low correlation (r<0.7)

y		x	AGE	HEIGHT	WEIGHT	L1	W1	W3	W4	W5	W6	W7	W8	H3	H4	H5	G1	G3	BALLGIRT	ANKLEGIR
			year	cm	kg	mm	mm	mm	mm	mm	mm	mm	mm	mm	mm	mm	mm	mm	mm	mm
HEIGHT	cm	r	0.520																	
		m																		
		b																		
WEIGHT	kg	r	0.459	0.832																
		m		0.737																
		b		-70.632																
L1	mm	r	0.225	0.759	0.690															
		m		1.089																
		b		84.452																
L2	mm	r	0.249	0.771	0.702	0.995														
		m		1.082	1.113	0.973														
		b		87.383	205.027	8.524														
LP1	mm	r				0.250														
		m																		
		b																		
LP2	mm	r				0.502														
		m																		
		b																		
LP3	mm	r				0.681														
		m																		
		b																		
LP4	mm	r				0.855														
		m				0.828														
		b				-23.543														
LP5	mm	r				0.883														
		m				0.764														
		b				-17.064														
LP6	mm	r				0.883														
		m				0.853														
		b				-2.201														
LP7	mm	r				0.138														
		m																		
		b																		
LP8	mm	r				0.425														
		m																		
		b																		
LP9	mm	r				0.690													0.046	0.173
		m																		
		b																		
LP10	mm	r				0.715														
		m				0.740														
		b				-34.365														
LP11	mm	r				0.513														
		m																		
		b																		
LP12	mm	r				0.856														
		m				0.865														
		b				-15.090														
LP13	mm	r				0.754														
		m				0.666														
		b				23.066														
W1	mm	r	0.361	0.565	0.596	0.671						0.607	0.659						0.384	
		m																		
		b																		
W2	mm	r					0.525	0.826				0.462	0.503						0.112	
		m						0.709												
		b						6.773												
W3	mm	r										0.485	0.480						0.175	
		m																		
		b																		
W4	mm	r										0.399	0.451						0.308	
		m																		
		b																		
W5	mm	r										0.358	0.312						0.124	
		m																		
		b																		
W6	mm	r										0.262	0.311						0.268	
		m																		
		b																		
W7	mm	r	0.347	0.664	0.669	0.670							0.951						0.539	
		m											0.994							
		b											3.148							
W8	mm	r	0.347	0.680	0.688	0.250						0.951							0.518	
		m										0.909								
		b										7.113								
C1	mm	r							0.583		0.687	0.058	0.056							
		m																		
		b																		
C2	mm	r						0.873		0.950		0.330	0.276							
		m						0.919		0.912										
		b						-6.487		-3.652										
H1	mm	r																	0.172	
		m																		
		b																		

y		x	AGE	HEIGHT	WEIGHT	L1	W1	W3	W4	W5	W6	W7	W8	H3	H4	H5	G1	G3	BALLGIRT	ANKLEGIR
			year	cm	kg	mm	mm	mm	mm	mm	mm	mm	mm	mm	mm	mm	mm	mm	mm	mm
H2	mm	r																	0.306	
		m																		
		b																		
H3	mm	r																	0.343	
		m																		
		b																		
H4	mm	r																	0.318	
		m																		
		b																		
H5	mm	r																	0.158	
		m																		
		b																		
H6	mm	r														**0.744**			0.074	
		m														0.645				
		b														4.942				
G1	mm	r												0.455					0.177	
		m																		
		b																		
G2	mm	r													0.200				0.014	
		m																		
		b																		
G3	mm	r														**0.772**			0.149	
		m														0.972				
		b														2.765				
BALLGIRT	mm	r	0.499	0.488	0.552	0.370						0.539	0.518					0.149		
		m																		
		b																		
HEELGIRT	mm	r			0.471							0.448	0.424				0.125		**0.759**	
		m																	1.140	
		b																	50.776	
ANKLEGIR	mm	r			0.673							0.537	0.524						**0.721**	
		m																	0.789	
		b																	18.887	
ABOVEAN	mm	r																		
		m																		
		b																		

Multiple linear regression

Table IV-2.2b

y		x	Coefficients for						
			r	HEIGHT	L1	W7	H5	G3	BALLGIRT	b
BALLGIRT	mm		0.539							
			0.567							
			0.540							
			0.540							
			0.541							
W7	mm		0.602							
			0.607							
			0.613							

Remarks: *r* coefficient of linear correlation

Regression equations are in form of y = m x + b

Irrelevant relationship

"Selfcorrelation" (r=1)

Bold = strong relation (r>0.7)

Equation parameters are missing for cases of low correlation (r<0.7)

y		x	AGE	HEIGHT	WEIGHT	L1	W1	W3	W4	W5	W6	W7	W8	H3	H4	H5	G1	G3	BALLGIRT	ANKLEGIR
			year	cm	kg	mm	mm	mm	mm	mm	mm	mm	mm	mm	mm	mm	mm	mm	mm	mm
HEIGHT	cm	r	0.085																	
		m																		
		b																		
WEIGHT	kg	r	0.178	0.692																
		m																		
		b																		
L1	mm	r	0.259	0.662	0.525															
		m																		
		b																		
L2	mm	r	0.253	0.659	0.528	0.995														
		m				0.961														
		b				10.702														
LP1	mm	r				0.279														
		m																		
		b																		
LP2	mm	r				0.527														
		m																		
		b																		
LP3	mm	r				0.670														
		m																		
		b																		
LP4	mm	r				0.830														
		m				0.816														
		b				-21.779														
LP5	mm	r				0.830														
		m				0.816														
		b				-29.014														
LP6	mm	r				0.885														
		m				0.948														
		b				-24.609														
LP7	mm	r				0.211														
		m																		
		b																		
LP8	mm	r				0.474														
		m																		
		b																		
LP9	mm	r				0.681													0.053	0.120
		m																		
		b																		
LP10	mm	r				0.747														
		m				0.790														
		b				-43.331														
LP11	mm	r				0.615														
		m																		
		b																		
LP12	mm	r				0.852														
		m				0.853														
		b				-9.968														
LP13	mm	r				0.930														
		m				0.760														
		b				2.125														
W1	mm	r	0.016	0.439	0.528	0.528						0.523	0.567						0.265	
		m																		
		b																		
W2	mm	r					0.558	0.858				0.399	0.443						0.088	
		m						0.865												
		b						-2.011												
W3	mm	r										0.456	0.448						0.174	
		m																		
		b																		
W4	mm	r										0.339	0.401						0.170	
		m																		
		b																		
W5	mm	r										0.354	0.278						0.181	
		m																		
		b																		
W6	mm	r										0.210	0.273						0.144	
		m																		
		b																		
W7	mm	r	0.001	0.501	0.565	0.551							0.936						0.450	
		m											0.966							
		b											5.490							
W8	mm	r	0.059	0.517	0.572	0.573						0.936							0.404	
		m										0.908								
		b										7.175								
C1	mm	r							0.469		0.562	0.051	0.038							
		m																		
		b																		
C2	mm	r						0.846		0.939		0.352	0.266							
		m						0.892		0.923										
		b						-4.427		-4.068										
H1	mm	r																	0.054	
		m																		
		b																		

y		x	AGE	HEIGHT	WEIGHT	L1	W1	W3	W4	W5	W6	W7	W8	H3	H4	H5	G1	G3	BALLGIRT	ANKLEGIR
			year	cm	kg	mm	mm	mm	mm	mm	mm	mm	mm	mm	mm	mm	mm	mm	mm	mm
H2	mm	r																	0.026	
		m																		
		b																		
H3	mm	r																	0.044	
		m																		
		b																		
H4	mm	r																	0.084	
		m																		
		b																		
H5	mm	r																	0.073	
		m																		
		b																		
H6	mm	r														**0.829**			0.053	
		m														**0.712**				
		b														**3.060**				
G1	mm	r												0.426					0.055	
		m																		
		b																		
G2	mm	r													0.248				0.014	
		m																		
		b																		
G3	mm	r														**0.908**			0.065	
		m														**0.881**				
		b														**4.857**				
BALLGIRT	mm	r	0.283	0.228	0.430	0.203						0.450	0.404					0.065		
		m																		
		b																		
HEELGIRT	mm	r			0.436							0.338	0.282				0.032		**0.715**	
		m																	**0.936**	
		b																	**89.650**	
ANKLEGIR	mm	r			0.667							0.474	0.417						0.639	
		m																		
		b																		
ABOVEAN	mm	r			0.185							0.268	0.273						0.010	0.019
		m																		
		b																		

Multiple linear regression Table IV-2.3b

y		x	Coefficients for						
		r	HEIGHT	L1	W7	H5	G3	BALLGIRT	b
BALLGIRT	mm	0.453							
		0.450							
		0.450							
		0.451							
		0.451							
W7	mm	0.485							
		0.484							
		0.486							

Remarks: *r* coefficient of linear correlation
Regression equations are in form of $y = m x + b$
Irrelevant relationship
"Selfcorrelation" (r=1)
Bold = strong relation (r>0.7)
Equation parameters are missing for cases of low correlation (r<0.7)

y		x	AGE	HEIGHT	WEIGHT	L1	W1	W3	W4	W5	W6	W7	W8	H3	H4	H5	G1	G3	BALLGIRT	ANKLEGIR
			year	cm	kg	mm	mm	mm	mm	mm	mm	mm	mm	mm	mm	mm	mm	mm	mm	mm
HEIGHT	cm	r	0.107																	
		m																		
		b																		
WEIGHT	kg	r	0.221	0.438																
		m																		
		b																		
L1	mm	r	0.074	0.560	0.390															
		m																		
		b																		
L2	mm	r	0.052	0.578	0.407	0.992														
		m				0.971														
		b				8.856														
LP1	mm	r				0.141														
		m																		
		b																		
LP2	mm	r				0.527														
		m																		
		b																		
LP3	mm	r				0.578														
		m																		
		b																		
LP4	mm	r				0.716														
		m				0.733														
		b				-0.733														
LP5	mm	r				0.751														
		m				0.704														
		b				-3.639														
LP6	mm	r				0.783														
		m				0.710														
		b				34.529														
LP7	mm	r				0.334														
		m																		
		b																		
LP8	mm	r				0.255														
		m																		
		b																		
LP9	mm	r				0.484													0.046	0.002
		m																		
		b																		
LP10	mm	r				0.496														
		m																		
		b																		
LP11	mm	r				0.765														
		m				0.417														
		b				-6.134														
LP12	mm	r				0.802														
		m				0.764														
		b				13.398														
LP13	mm	r				0.831														
		m				0.763														
		b				0.863														
W1	mm	r	0.192	0.278	0.398	0.397						0.486	0.518						0.163	
		m																		
		b																		
W2	mm	r					0.433	0.755				0.459	0.448						0.222	
		m						0.629												
		b						11.231												
W3	mm	r										0.424	0.331						0.454	
		m																		
		b																		
W4	mm	r										0.285	0.427						0.138	
		m																		
		b																		
W5	mm	r										0.330	0.184						0.408	
		m																		
		b																		
W6	mm	r										0.248	0.391						0.157	
		m																		
		b																		
W7	mm	r	0.097	0.318	0.367	0.485							0.930						0.474	
		m											0.990							
		b											3.940							
W8	mm	r	0.118	0.370	0.445	0.482						0.930							0.399	
		m										0.873								
		b										11.662								
C1	mm	r							0.487		0.517	0.052	0.067							
		m																		
		b																		
C2	mm	r						0.896		0.962		0.327	0.180							
		m						1.147		1.020										
		b						-21.176		-11.237										
H1	mm	r																	0.217	
		m																		
		b																		

		x	AGE	HEIGHT	WEIGHT	L1	W1	W3	W4	W5	W6	W7	W8	H3	H4	H5	G1	G3	BALLGIRT	ANKLEGIR
y			year	cm	kg	mm	mm	mm	mm	mm	mm	mm	mm	mm	mm	mm	mm	mm	mm	mm
H2	mm	r																	0.054	
		m																		
		b																		
H3	mm	r																	0.177	
		m																		
		b																		
H4	mm	r																	0.265	
		m																		
		b																		
H5	mm	r																	0.257	
		m																		
		b																		
H6	mm	r														**0.726**			0.337	
		m														0.665				
		b														6.258				
G1	mm	r												0.508					0.110	
		m																		
		b																		
G2	mm	r													0.244				0.214	
		m																		
		b																		
G3	mm	r														**0.811**			0.303	
		m														0.776				
		b														10.616				
BALLGIRT	mm	r	0.047	0.245	0.282	0.374						0.474	0.399					0.303		
		m																		
		b																		
HEELGIRT	mm	r			0.124							0.206	0.121				0.030		**0.765**	
		m																	1.144	
		b																	46.608	
ANKLEGIR	mm	r			0.390							0.280	0.222						**0.733**	
		m																	0.762	
		b																	22.120	
ABOVEAN	mm	r			0.104							0.223	0.152						0.247	0.055
		m																		
		b																		

Multiple linear regression Table IV-2.4b

y	x	r	Coefficients for HEIGHT	L1	W7	H5	G3	BALLGIRT	b
BALLGIRT	mm	0.502							
		0.484							
		0.499							
		0.525							
		0.526							
W7	mm	0.474							
		0.484							
		0.491							

Remarks: *r* coefficient of linear correlation

Regression equations are in form of $y = m x + b$

Irrelevant relationship

"Selfcorrelation" (r=1)

Bold = strong relation (r>0.7)

Equation parameters are missing for cases of low correlation (r<0.7)

y		x	AGE	HEIGHT	WEIGHT	L1	W1	W3	W4	W5	W6	W7	W8	H3	H4	H5	G1	G3	BALLGIRT	ANKLEGIR
			year	cm	kg	mm	mm	mm	mm	mm	mm	mm	mm	mm	mm	mm	mm	mm	mm	mm
HEIGHT	cm	r	0.191	[redacted]																
		m		[redacted]																
		b		[redacted]																
WEIGHT	kg	r	0.550	0.399	[redacted]															
		m			[redacted]															
		b			[redacted]															
L1	mm	r	0.024	0.347	0.203	[redacted]														
		m				[redacted]														
		b				[redacted]														
L2	mm	r	0.001	0.382	0.227	0.990														
		m				1.000														
		b				0.774														
LP1	mm	r				0.112														
		m																		
		b																		
LP2	mm	r				0.453														
		m																		
		b																		
LP3	mm	r				0.460														
		m																		
		b																		
LP4	mm	r				0.625														
		m																		
		b																		
LP5	mm	r				0.599														
		m																		
		b																		
LP6	mm	r				0.654														
		m																		
		b																		
LP7	mm	r				0.248														
		m																		
		b																		
LP8	mm	r				0.278														
		m																		
		b																		
LP9	mm	r				0.382													0.046	0.149
		m																		
		b																		
LP10	mm	r				0.350														
		m																		
		b																		
LP11	mm	r				0.571														
		m																		
		b																		
LP12	mm	r				0.616														
		m																		
		b																		
LP13	mm	r				0.760														
		m				0.795														
		b				-8.173														
W1	mm	r	0.030	0.175	0.124	0.354	[redacted]					0.422	0.360						0.265	
		m					[redacted]													
		b					[redacted]													
W2	mm	r					0.265	0.808				0.290	0.273						0.307	
		m						0.674												
		b						8.709												
W3	mm	r						[redacted]				0.307	0.216						0.467	
		m						[redacted]												
		b						[redacted]												
W4	mm	r							[redacted]			0.434	0.563						0.181	
		m							[redacted]											
		b							[redacted]											
W5	mm	r								[redacted]		0.222	0.071						0.434	
		m								[redacted]										
		b								[redacted]										
W6	mm	r									[redacted]	0.315	0.455						0.279	
		m									[redacted]									
		b									[redacted]									
W7	mm	r	0.044	0.328	0.242	0.370						[redacted]	0.929						0.352	
		m										[redacted]	0.948							
		b										[redacted]	7.688							
W8	mm	r	0.003	0.341	0.245	0.363						0.929	[redacted]						0.287	
		m										0.911	[redacted]							
		b										6.804	[redacted]							
C1	mm	r							0.517		0.516	0.213	0.242							
		m																		
		b																		
C2	mm	r						0.867		0.939		0.184	0.033							
		m						1.086		0.989										
		b						-14.573		-7.605										
H1	mm	r																	0.020	
		m																		
		b																		

y		x	AGE	HEIGHT	WEIGHT	L1	W1	W3	W4	W5	W6	W7	W8	H3	H4	H5	G1	G3	BALLGIRT	ANKLEGIR
			year	cm	kg	mm	mm	mm	mm	mm	mm	mm	mm	mm	mm	mm	mm	mm	mm	mm
H2	mm	r																	0.105	
		m																		
		b																		
H3	mm	r																	0.047	
		m																		
		b																		
H4	mm	r																	0.131	
		m																		
		b																		
H5	mm	r																	0.030	
		m																		
		b																		
H6	mm	r													**0.729**			0.114	
		m													0.546				
		b													9.988				
G1	mm	r											0.499					0.024	
		m																		
		b																		
G2	mm	r												0.046				0.060	
		m																		
		b																		
G3	mm	r													**0.904**			0.126	
		m													0.780				
		b													8.844				
BALLGIRT	mm	r	0.154	0.109	0.023	0.269						0.352	0.287					0.126		
		m																		
		b																		
HEELGIRT	mm	r			0.153							0.214	0.176				0.222		0.599	
		m																		
		b																		
ANKLEGIR	mm	r			0.156							0.117	0.022						0.580	
		m																		
		b																		
ABOVEAN	mm	r			0.150							0.118	0.051						0.105	0.364
		m																		
		b																		

Multiple linear regression Table IV-2.5b

y		x		Coefficients for					
			r	HEIGHT	L1	W7	H5	G3	BALLGIRT	b
BALLGIRT	mm		0.382							
			0.352							
			0.355							
			0.354							
			0.402							
W7	mm		0.410							
			0.411							
			0.413							

Remarks: *r* coefficient of linear correlation

Regression equations are in form of $y = m x + b$

Irrelevant relationship

"Selfcorrelation" (r=1)

Bold = strong relation (r>0.7)

Equation parameters are missing for cases of low correlation (r<0.7)

Computation of size ranges

INPUT DATA				
	System:	English	Average:	30.98
	Increment:	0.5	St. deviation:	1.52
	Batch [pairs]:	60	Coverage [%]:	88

Linear	*Normal*	*Lambda*	*Probability*	*Coverage [%]*			*Pairs in batch*	
size				*by sizes*	*cummul.*	*included*	*comp.*	***correct.***
22.0	10.0	-5.91	0.000000	0.000	0.000	0.000	0	
22.5	10.5	-5.58	0.000000	0.000	0.000	0.000	0	
23.0	11.0	-5.25	0.000000	0.000	0.000	0.000	0	
23.5	11.5	-4.92	0.000002	0.000	0.000	0.000	0	
24.0	12.0	-4.59	0.000011	0.000	0.000	0.000	0	
24.5	12.5	-4.26	0.000045	0.001	0.001	0.000	0	
25.0	0.0	-3.93	0.000174	0.004	0.005	0.000	0	
25.5	0.5	-3.61	0.000600	0.013	0.018	0.000	0	
26.0	1.0	-3.28	0.001862	0.041	0.058	0.000	0	
26.5	1.5	-2.95	0.005183	0.116	0.174	0.000	0	
27.0	2.0	-2.62	0.012946	0.298	0.472	0.000	0	
27.5	2.5	-2.29	0.029020	0.690	1.162	0.000	0	
28.0	3.0	-1.96	0.058381	1.438	2.600	0.000	0	
28.5	3.5	-1.63	0.105403	2.694	5.294	0.000	0	
29.0	4.0	-1.30	0.170783	4.543	9.836	4.543	3	**3**
29.5	4.5	-0.97	0.248337	6.893	16.730	6.893	5	**5**
30.0	5.0	-0.64	0.324075	9.415	26.144	9.415	6	**6**
30.5	5.5	-0.32	0.379538	11.573	37.717	11.573	8	**8**
31.0	**6.0**	*0.01*	0.398908	12.803	50.520	12.803	9	**9**
31.5	6.5	0.34	0.376267	12.750	63.270	12.750	9	**9**
32.0	7.0	0.67	0.318512	11.427	74.697	11.427	8	**8**
32.5	7.5	1.00	0.241971	9.218	83.915	9.218	6	**6**
33.0	8.0	1.33	0.164970	6.693	90.609	6.693	4	**4**
33.5	8.5	1.66	0.100938	4.373	94.982	4.373	3	**2**
34.0	9.0	1.99	0.055426	2.572	97.554	0.000	0	
34.5	9.5	2.32	0.027313	1.361	98.915	0.000	0	
35.0	10.0	2.64	0.012079	0.648	99.563	0.000	0	
35.5	10.5	2.97	0.004794	0.278	99.840	0.000	0	
36.0	11.0	3.30	0.001708	0.107	99.947	0.000	0	
36.5	11.5	3.63	0.000546	0.037	99.984	0.000	0	
37.0	12.0	3.96	0.000157	0.012	99.996	0.000	0	
37.5	12.5	4.29	0.000040	0.003	99.999	0.000	0	
38.0	13.0	4.62	0.000009	0.001	100.000	0.000	0	
38.5	13.5	4.95	0.000002	0.000	100.000	0.000	0	
39.0	14.0	5.28	0.000000	0.000	100.000	0.000	0	
39.5	14.5	5.61	0.000000	0.000	100.000	0.000	0	
40.0	15.0	5.93	0.000000	0.000	100.000	0.000	0	
Total:				100.000		89.689	61	**60**

Recommended size ranges for Enlish HALF size system

English size		Children		Boys		Girls		Men		Women	
Linear	*Normal*	%	*Batch*	%	*Batch*	%	*Batch*	%	*Batch*	%	*Batch*
16.5	4.5	0.040									
17.0	5.0	0.073									
17.5	5.5	0.128									
18.0	6.0	0.216									
18.5	6.5	0.352									
19.0	7.0	0.554									
19.5	7.5	0.840									
20.0	8.0	1.229									
20.5	8.5	1.734									
21.0	9.0	2.361	3	0.001		0.001					
21.5	9.5	3.099	3	0.003		0.003					
22.0	10.0	3.924	4	0.008		0.011					
22.5	10.5	4.792	5	0.020		0.031					
23.0	11.0	5.645	6	0.047		0.082					
23.5	11.5	6.415	7	0.104		0.199					
24.0	12.0	7.031	8	0.217		0.442					
24.5	12.5	7.432	9	0.426		0.900		0.001		0.001	
25.0	13.0	7.579	**9**	0.783		1.680		0.004		0.006	
25.5	0.5	7.454	9	1.348		2.874		0.013		0.040	
26.0	1.0	7.071	8	2.176		4.510	5	0.041		0.194	
26.5	1.5	6.471	7	3.292	4	6.490	7	0.116		0.747	
27.0	2.0	5.711	6	4.668	5	8.563	10	0.298		2.270	
27.5	2.5	4.862	5	6.204	7	10.361	12	0.690		5.461	6
28.0	3.0	3.992	4	7.730	9	11.496	**13**	1.438		10.417	11
28.5	3.5	3.162	4	9.028	10	11.697	13	2.694		15.769	17
29.0	4.0	2.416	3	9.883	**10**	10.914	12	4.543	5	18.957	**21**
29.5	4.5	1.780		10.142	11	9.338	10	6.893	8	18.104	20
30.0	5.0	1.265		9.756	11	7.327	8	9.415	10	13.734	16
30.5	5.5	0.867		8.797	10	5.272	6	11.573	13	8.273	9
31.0	6.0	0.574		7.436	8	3.478	4	12.803	**14**	3.953	
31.5	6.5	0.366		5.891	7	2.104		12.750	14	1.496	
32.0	7.0	0.225		4.375	5	1.167		11.427	13	0.448	
32.5	7.5	0.134		3.046	3	0.593		9.218	11	0.106	
33.0	8.0	0.076		1.988		0.277		6.693	7	0.020	
33.5	8.5	0.042		1.216		0.118		4.373	5	0.003	
34.0	9.0	0.022		0.697		0.046		2.572			
34.5	9.5			0.374		0.017		1.361			
35.0	10.0			0.189		0.005		0.648			
35.5	10.5			0.089		0.002		0.278			
36.0	11.0			0.039				0.107			
36.5	11.5			0.016				0.037			
37.0	12.0			0.006				0.012			
37.5	12.5			0.002				0.003			
38.0	13.0			0.001				0.001			
		99.936	100	99.999	100	99.999	100	100.000	100	100.000	100

Remark: Targeted coverage is 90%.
Middle sizes are highlighted

Recommended size ranges for Enlish WHOLE size system

English size		Children		Boys		Girls		Men		Women	
Linear	*Normal*	%	*Batch*	%	*Batch*	%	*Batch*	%	*Batch*	%	*Batch*
14	2	0.002									
15	3	0.009									
16	4	0.035									
17	5	0.122									
18	6	0.364									
19	7	0.944									
20	8	2.125									
21	9	4.155	5	0.002		0.002					
22	10	7.057	8	0.013		0.018					
23	11	10.414	11	0.076		0.135					
24	12	13.352	15	0.357		0.723					
25	13	14.876	**16**	1.298		2.768		0.006		0.012	
26	1	14.403	16	3.667		7.600	8	0.067		0.332	
27	2	12.119	13	8.074	9	15.018	17	0.487		3.686	
28	3	8.861	10	13.878	15	21.435	23	2.346		16.644	18
29	4	5.629	6	18.640	20	22.138	**24**	7.538	8	32.931	**35**
30	5	3.106		19.579	**21**	16.550	18	16.278	17	30.567	33
31	6	1.489		16.084	18	8.940	10	23.782	**25**	13.188	14
32	7	0.620		10.329	11	3.479		23.599	25	2.452	
33	8	0.224		5.181	6	0.971		15.904	17	0.183	
34	9	0.070		2.026		0.194		7.250	8	0.005	
35	10	0.019		0.617		0.027		2.221			
36	11	0.005		0.146		0.003		0.454			
37	12	0.001		0.027				0.061			
38	13			0.004				0.005			
		99.999	100	99.999	100	100.000	100	99.999	100	100.000	100

Remark: Targeted coverage is 90%.

Middle sizes are highlighted

Recommended size ranges for French POINT size system

French point	Children %	Children Batch	Boys %	Boys Batch	Girls %	Girls Batch	Men %	Men Batch	Women %	Women Batch
18	0.001									
19	0.004									
20	0.012									
21	0.035									
22	0.093									
23	0.226									
24	0.503									
25	1.024									
26	1.902									
27	3.230	4	0.001		0.001					
28	5.014	6	0.006		0.006					
29	7.115	8	0.027		0.037					
30	9.230	10	0.100		0.171					
31	10.945	12	0.323		0.637		0.001			
32	11.866	**13**	0.894		1.910		0.006		0.007	
33	11.760	13	2.117		4.607		0.036		0.113	
34	10.655	12	4.297	5	8.956	10	0.180		1.000	
35	8.825	10	7.475	8	14.042	16	0.709		5.056	
36	6.682	7	11.147	12	17.769	**20**	2.200		14.889	16
37	4.625	5	14.254	15	18.153	20	5.384	7	26.025	28
38	2.926		15.630	**17**	14.973	17	10.395	11	27.373	**30**
39	1.692		14.698	16	9.969	11	15.859	17	17.348	19
40	0.895		11.854	13	5.354	6	19.131	**21**	6.548	7
41	0.432		8.197	9	2.318		18.254	20	1.445	
42	0.191		4.860	5	0.808		13.777	15	0.183	
43	0.077		2.470		0.226		8.219	9	0.013	
44	0.028		1.075		0.051		3.873		0.001	
45	0.010		0.401		0.009		1.439			
46	0.003		0.128		0.001		0.421			
47	0.001		0.035				0.097			
48			0.008				0.018			
49			0.002				0.002			
	99.999	100	99.999	100	100.000	100	100.000	100	100.000	100

*Remark*Targeted coverage is 90%.

Middle sizes are highlighted

Width groups created on the basis of BALL GIRTH

Size	CHILDREN (1)							BOYS (2)							GIRLS (3)							MEN (4)							WOMEN (5)						
	n	*m*	*s*	*Min*	*Max*	*4s/7*	*2s/6*	*n*	*m*	*s*	*Min*	*Max*	*4s/7*	*2s/6*	*n*	*m*	*s*	*Min*	*Max*	*4s/7*	*2s/6*	*n*	*m*	*s*	*Min*	*Max*	*4s/7*	*2s/6*	*n*	*m*	*s*	*Min*	*Max*	*4s/7*	*2s/6*
5.5	5	140.0	0.0	140	140	0	0																												
6.0	5	148.0	16.4	130	170	9	5																												
6.5	8	137.5	4.6	130	140	2	1																												
7.0	11	143.6	11.2	130	160	6	3																												
7.5	15	150.0	7.6	140	160	4	2																												
8.0	20	151.5	10.4	130	170	5	3																												
8.5	21	157.1	9.6	140	180	5	3																												
9.0	43	155.4	11.8	130	180	6	3																												
9.5	45	159.8	10.8	140	190	6	3																												
10.0	50	160.6	11.1	140	190	6	3																												
10.5	70	165.1	12.3	130	210	7	4								1	190.0	0.0	190	190	0	0														
11.0	70	164.9	12.2	140	190	6	4								0																				
11.5	81	166.4	11.0	125	190	6	3								2	195.0	7.1	190	200	4	2														
12.0	108	170.7	13.7	135	200	7	4	1	180.0	0.0	180	180	0	0	4	190.0	8.2	180	200	4	2														
12.5	103	172.2	14.2	149	210	8	4	4	187.5	12.6	170	200	7	4	6	196.7	8.2	190	210	4	2														
13.0	*94*	*176.0*	*14.1*	*150*	*210*	*8*	*4*	6	193.3	17.5	180	220	10	5	11	190.9	10.4	170	210	5	3														
0.5	93	176.0	14.5	125	210	8	4	7	194.3	9.8	180	210	5	3	12	191.7	11.2	170	200	6	3														
1.0	108	179.8	13.9	150	210	7	4	10	191.0	14.5	170	210	8	4	18	193.3	10.3	180	210	5	3														
1.5	119	181.3	12.8	150	210	7	4	23	196.5	14.0	170	220	8	4	41	198.7	13.7	168	220	7	4								1	210.0	0.0	210	210	0	0
2.0	85	182.6	14.4	150	210	8	4	36	194.0	14.1	170	220	8	4	42	195.6	13.6	160	220	7	4								0						
2.5	89	184.2	14.2	150	210	8	4	45	196.8	17.7	160	230	10	5	54	197.2	16.2	160	220	9	5	3	210.0	0.0	210	210	0	0	10	198.0	13.2	180	220	7	4
3.0	71	189.3	11.9	160	215	6	3	38	200.7	17.6	160	230	10	5	*54*	*198.7*	*16.5*	*170*	*240*	*9*	*5*	7	207.1	16.0	180	230	9	5	7	206.4	13.8	190	225	7	4
3.5	50	191.8	13.2	170	225	7	4	46	203.9	17.3	170	230	9	5	54	195.8	12.9	165	220	7	4	18	219.7	16.0	185	250	9	5	35	206.3	15.2	170	230	8	5
4.0	44	191.8	15.3	160	240	8	5	*55*	*206.1*	*14.9*	*180*	*240*	*8*	*4*	76	201.1	13.7	175	230	7	4	26	213.4	14.5	190	250	8	4	*25*	*210.4*	*13.8*	*180*	*250*	*7*	*4*
4.5	19	191.0	10.9	160	210	6	3	57	204.2	17.5	170	250	9	5	39	196.5	14.2	170	240	8	4	32	216.9	15.1	190	260	8	5	19	209.7	15.9	170	240	9	5
5.0	17	199.4	11.9	168	220	6	3	67	209.5	18.3	180	250	10	6	42	199.9	14.0	170	230	7	4	41	217.1	15.7	180	250	8	5	12	204.6	17.3	180	240	9	5
5.5	11	201.4	10.0	190	220	5	3	54	212.2	18.2	170	250	10	6	23	205.6	11.3	190	225	6	3	52	221.4	18.7	180	260	10	6	8	210.0	15.8	180	230	9	5
6.0	3	200.0	18.0	180	215	10	6	48	208.1	17.8	180	250	10	5	21	206.0	14.7	180	240	8	4	*73*	*223.0*	*17.2*	*190*	*270*	*9*	*5*	7	224.3	9.3	210	235	5	3
6.5	3	210.0	10.0	200	220	5	3	32	209.0	16.7	173	252	9	5	12	202.9	9.2	190	215	5	3	62	231.7	17.0	200	280	9	5	4	224.0	13.4	210	236	7	4
7.0	2	189.0	26.9	170	208	15	8	30	211.1	16.2	180	250	9	5	7	206.6	10.7	190	220	6	3	50	230.7	16.8	185	260	9	5	1	210.0	0.0	210	210	0	0
7.5								21	220.0	16.9	190	265	9	5								52	230.2	17.7	200	270	10	5							
8.0								16	215.8	15.3	190	242	8	5								35	228.3	18.0	190	260	10	6							
8.5								7	216.4	16.5	185	230	9	5								12	240.3	17.5	210	260	9	5							
9.0								4	224.3	25.3	210	262	14	8								11	237.0	25.8	180	270	14	8							
9.5																						10	238.7	11.6	225	260	6	3							
10.0																						3	240.7	17.9	220	252	10	5							
10.5																						2	237.5	24.8	220	255	14	8							
11.0																						1	270.0	0.0	270	270	0	0							
Group:	1,463	174.6	17.6	125	240	10	5	607	205.4	18.1	160	265	10	6	519	198.4	14.0	160	240	8	4	490	225.4	18.4	180	280	10	6	129	208.6	15.3	170	250	8	5

Remark: *n* - number of observations (cases)
m - average
s - standard deviation

Width groups created on the basis of FOOT WIDTH

Size	CHILDREN (1) *n*	*m*	*s*	*Min*	*Max*	*4s/4*	*2s/3*
5.5	5	70.8	10.0	56.6	80.5	9	6
6.0	5	67.6	4.1	61.5	71.2	4	2
6.5	8	72.5	5.7	65.6	83.9	5	3
7.0	11	70.7	6.8	53.0	76.8	6	4
7.5	15	72.5	4.4	63.7	81.1	4	2
8.0	20	76.3	5.4	67.6	85.2	5	3
8.5	21	74.4	4.9	62.7	81.9	4	3
9.0	43	77.2	6.1	64.8	91.2	6	4
9.5	45	81.2	6.6	70.7	101.4	6	4
10.0	50	82.6	6.0	66.6	96.7	6	4
10.5	70	84.1	6.1	69.6	101.5	6	4
11.0	70	84.5	5.4	72.2	96.8	5	3
11.5	81	87.2	5.4	76.5	104.8	5	3
12.0	108	87.8	5.0	76.5	104.5	5	3
12.5	103	89.2	5.6	77.8	103.6	5	3
13.0	*94*	*90.1*	*5.9*	*73.7*	*108.8*	*5*	*3*
0.5	93	92.1	6.9	76.7	125.0	6	4
1.0	108	92.5	5.6	80.2	107.1	5	3
1.5	119	93.4	5.3	79.8	114.1	5	3
2.0	85	94.9	6.3	80.9	112.6	6	4
2.5	89	96.6	5.7	82.0	116.3	5	3
3.0	71	96.6	5.8	85.0	109.2	5	3
3.5	50	97.4	5.8	84.6	114.2	5	3
4.0	44	99.5	5.0	85.1	109.9	5	3
4.5	19	102.8	7.8	91.4	118.2	7	5
5.0	17	102.2	7.6	90.6	117.1	7	5
5.5	11	101.9	5.9	90.0	111.0	5	3
6.0	3	109.8	7.2	105.2	118.1	7	4
6.5	3	105.8	11.9	92.2	114.1	11	7
7.0	2	101.4	7.1	96.4	106.4	7	4
Group:	1,463	89.8	9.1	53.0	125.1	9	6

Size	BOYS (2) *n*	*m*	*s*	*Min*	*Max*	*4s/4*	*2s/3*
12.0	1	94.8	0.0	94.8	94.8	0	0
12.5	4	93.0	3.8	88.1	97.4	3	2
13.0	6	86.7	4.0	80.8	91.7	4	2
0.5	7	95.5	5.9	88.0	107.3	5	3
1.0	10	92.0	4.2	87.3	101.1	4	2
1.5	23	98.8	6.2	91.2	114.8	6	4
2.0	36	98.5	6.2	82.8	117.2	6	4
2.5	45	100.3	7.4	85.9	116.5	7	4
3.0	38	101.9	7.5	86.3	114.4	7	4
3.5	46	102.5	6.0	88.0	116.1	6	4
4.0	*55*	*105.5*	*6.3*	*89.0*	*119.2*	*6*	*4*
4.5	57	105.6	6.8	93.3	120.9	6	4
5.0	67	107.3	5.5	94.5	119.2	5	3
5.5	54	110.4	5.9	97.5	124.4	5	3
6.0	48	109.9	5.8	95.6	119.0	5	3
6.5	32	111.6	6.7	95.2	125.6	6	4
7.0	30	112.9	6.4	100.3	127.9	6	4
7.5	21	114.6	7.1	99.3	127.1	7	4
8.0	16	114.4	5.1	107.5	124.8	5	3
8.5	7	116.8	5.5	109.0	124.1	5	3
9.0	4	116.7	7.5	110.4	126.7	7	5
Group:	607	105.8	8.4	80.8	127.9	8	5

Size	GIRLS (3) *n*	*m*	*s*	*Min*	*Max*	*4s/4*	*2s/3*
10.5	1	90.6	0.0	90.6	90.6	0	0
11.0	0						
11.5	2	93.5	0.3	93.2	93.7	0	0
12.0	4	90.4	4.8	84.8	95.8	4	3
12.5	6	97.4	7.5	85.8	107.0	7	4
13.0	11	96.7	6.4	88.6	105.9	6	4
0.5	12	93.0	4.3	86.3	100.9	4	2
1.0	18	95.2	5.5	84.8	105.0	5	3
1.5	41	97.6	7.0	85.0	115.7	6	4
2.0	42	96.3	6.4	80.6	108.5	6	4
2.5	54	98.1	6.1	82.7	112.1	6	4
3.0	*54*	*99.7*	*5.3*	*91.2*	*116.6*	*5*	*3*
3.5	54	100.5	6.3	83.0	117.0	6	4
4.0	76	102.6	5.4	89.7	117.1	5	3
4.5	39	102.8	5.7	87.7	113.2	5	3
5.0	42	104.2	5.4	93.6	114.6	5	3
5.5	23	107.0	3.9	95.6	114.1	3	2
6.0	21	108.4	3.7	101.9	116.2	3	2
6.5	12	107.2	5.5	99.5	116.2	5	3
7.0	7	108.3	3.8	105.1	116.0	3	2
Group:	519	100.6	6.8	80.6	117.1	6	4

Size	MEN (4) *n*	*m*	*s*	*Min*	*Max*	*4s/4*	*2s/3*
3.0	3	99.9	1.0	98.9	100.7	0	0
3.5	7	103.6	4.4	97.0	111.2	4	2
4.0	18	109.7	9.0	97.9	130.6	8	5
4.5	26	108.3	6.7	94.2	121.7	6	4
5.0	32	111.0	8.7	94.1	131.8	8	5
5.5	41	111.7	6.3	99.9	129.0	6	4
6.0	52	111.1	6.3	94.2	123.6	6	4
6.5	*73*	*114.3*	*6.6*	*100.1*	*127.5*	*6*	*4*
7.0	62	113.7	5.7	99.5	124.9	5	3
7.5	50	116.3	6.8	104.0	133.4	6	4
8.0	52	117.0	7.4	101.3	132.5	7	4
8.5	35	116.2	5.7	102.0	131.1	5	3
9.0	12	121.5	9.5	99.9	133.3	9	6
9.5	11	120.6	5.7	112.6	129.8	5	3
10.0	10	124.5	4.7	118.4	132.5	4	3
10.5	3	127.8	3.1	124.5	130.6	3	2
11.0	2	125.4	5.0	121.9	128.9	4	3
	1	120.0	0.0	120.0	120.0	0	0
Group:	490	114.0	7.7	94.1	133.4	7	5

Size	WOMEN (5) *n*	*m*	*s*	*Min*	*Max*	*4s/4*	*2s/3*
2.0	1	103.1	0.0	103.1	103.1	0	0
2.5	0						
3.0	10	97.2	5.7	90.2	109.7	5	3
3.5	7	104.3	5.1	98.8	112.7	5	3
4.0	35	101.6	5.2	91.9	115.4	5	3
4.5	*25*	*104.1*	*5.0*	*93.9*	*113.4*	*4*	*3*
5.0	19	105.1	6.1	94.2	117.3	6	4
5.5	12	106.6	9.6	94.4	119.8	9	6
6.0	8	104.3	5.6	95.6	113.0	5	3
6.5	7	108.5	4.4	103.0	115.0	4	2
7.0	4	110.5	8.3	100.7	119.7	8	5
7.5	1	96.4	0.0	96.4	96.4	0	0
Group:	129	103.7	6.4	90.2	119.8	6	4

Remark: *n* - number of observations (cases)
m - average
s - standard deviation

Ball GIRTH increments by English half sizes

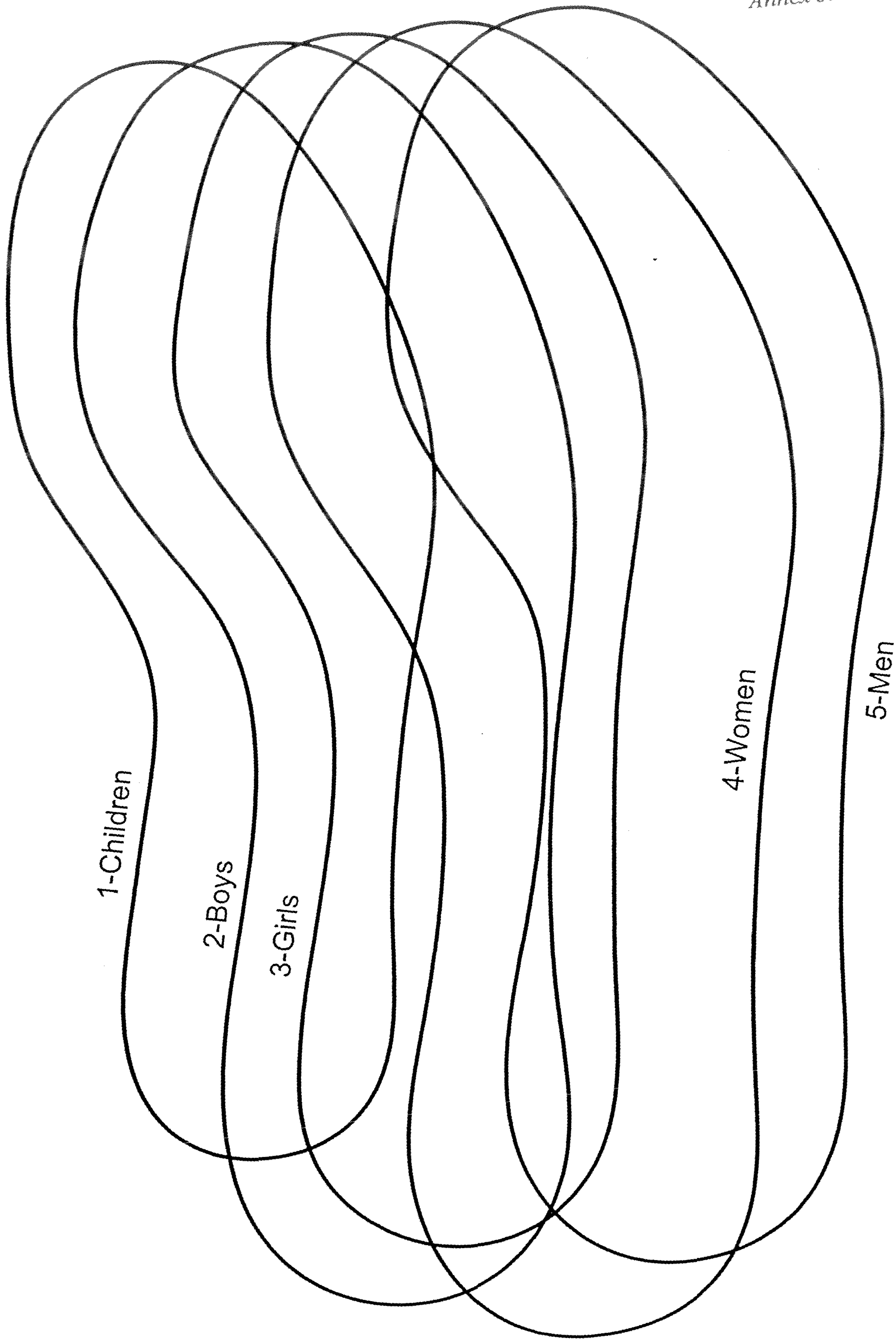
Size	CHILDREN (1)			BOYS (2)			GIRLS (3)			MEN (4)			WOMEN (5)		
	n	*x*	*Increment*	*n*	*x*	*Increment*	*n*	*x*	*Increment*	*n*	*x*	*Increment*	*n*	*x*	*Increment*
5.5	5	140.00													
6.0	5	148.00	8.00												
6.5	8	137.50	-10.50												
7.0	11	143.64	6.14												
7.5	15	150.00	6.36												
8.0	20	151.50	1.50												
8.5	21	157.14	5.64												
9.0	43	155.40	-1.74												
9.5	45	159.78	4.38												
10.0	50	160.64	0.86												
10.5	70	165.09	4.45				1	190.00							
11.0	70	164.86	-0.23				0								
11.5	81	166.38	1.52				2	195.00							
12.0	108	170.67	4.29	1	180.00		4	190.00	-5.00						
12.5	103	172.23	1.56	4	187.50	7.50	6	196.67	6.67						
13.0	*94*	*176.02*	*3.79*	6	193.33	5.83	11	190.91	-5.76						
0.5	93	175.97	-0.05	7	194.29	0.96	12	191.67	0.76						
1.0	108	179.81	3.84	10	191.00	-3.29	18	193.33	1.66						
1.5	119	181.25	1.44	23	196.52	5.52	41	198.66	5.33				1	210.00	
2.0	85	182.60	1.35	36	194.03	-2.49	42	195.60	-3.06				0		
2.5	89	184.17	1.57	45	196.78	2.75	54	197.19	1.59	3	210.00		10	198.00	
3.0	71	189.32	5.15	38	200.66	3.88	*54*	*198.65*	*1.46*	7	207.14	-2.86	7	206.43	8.43
3.5	50	191.78	2.46	46	203.91	3.25	54	195.83	-2.82	18	219.72	12.58	35	206.29	-0.14
4.0	44	191.84	0.06	*55*	*206.09*	*2.18*	76	201.08	5.25	26	213.42	-6.30	*25*	*210.40*	*4.11*
4.5	19	191.00	-0.84	57	204.16	-1.93	39	196.54	-4.54	32	216.87	3.45	19	209.74	-0.66
5.0	17	199.41	8.41	67	209.54	5.38	42	199.86	3.32	41	217.07	0.20	12	204.58	-5.16
5.5	11	201.36	1.95	54	212.20	2.66	23	205.57	5.71	52	221.44	4.37	8	210.00	5.42
6.0	3	200.00	-1.36	48	208.06	-4.14	21	205.95	0.38	*73*	*223.01*	*1.57*	7	224.29	14.29
6.5	3	210.00	10.00	32	208.97	0.91	12	202.92	-3.03	62	231.69	8.68	4	224.00	-0.29
7.0	2	189.00	-21.00	30	211.13	2.16	7	206.57	3.65	50	230.72	-0.97	1	210.00	-14.00
7.5				21	219.95	8.82				52	230.15	-0.57			
8.0				16	215.75	-4.20				35	228.31	-1.84			
8.5				7	216.43	0.68				12	240.33	12.02			
9.0				4	224.25	7.82				11	237.00	-3.33			
9.5										10	238.70	1.70			
10.0										3	240.67	1.97			
10.5										2	237.50	-3.17			
11.0										1	270.00	32.50			
Group:	1,463	174.62	2.26	607	205.41	1.50	519	198.43	1.14	490	225.36	2.17	129	208.61	1.79
Relevant:			2.30			1.64			1.27			2.43			1.99

Remark: *n* - number of cases
x - average ball girth (BALLGIRT)
Relevant - length sizes falling into the range providing 90% coverage in length

Ball WIDTH increments by English half sizes

Size	CHILDREN (1)			BOYS (2)			GIRLS (3)			MEN (4)			WOMEN (5)		
	n	*x*	*Increment*	*n*	*x*	*Increment*	*n*	*x*	*Increment*	*n*	*x*	*Increment*	*n*	*x*	*Increment*
5.5	5	70.75													
6.0	5	67.58	-3.17												
6.5	8	72.49	4.91												
7.0	11	70.68	-1.81												
7.5	15	72.45	1.77												
8.0	20	76.25	3.80												
8.5	21	74.38	-1.87												
9.0	43	77.22	2.84												
9.5	45	81.20	3.98												
10.0	50	82.64	1.44												
10.5	70	84.05	1.41				1	90.58							
11.0	70	84.47	0.42				0								
11.5	81	87.18	2.71				2	93.47							
12.0	108	87.77	0.59	1	94.78		4	90.41	-3.06						
12.5	103	89.16	1.39	4	92.98	-1.80	6	97.41	7.00						
13.0	*94*	*90.05*	*0.89*	6	86.74	-6.24	11	96.71	-0.70						
0.5	93	92.08	2.03	7	95.48	8.74	12	93.04	-3.67						
1.0	108	92.49	0.41	10	92.04	-3.44	18	95.23	2.19						
1.5	119	93.39	0.90	23	98.75	6.71	41	97.59	2.36				1	103.14	
2.0	85	94.88	1.49	36	98.50	-0.25	42	96.28	-1.31				0		
2.5	89	96.57	1.69	45	100.28	1.78	54	98.07	1.79	3	99.94		10	97.20	
3.0	71	96.60	0.03	38	101.88	1.60	*54*	*99.65*	*1.58*	7	103.62	3.68	7	104.27	7.07
3.5	50	97.44	0.84	46	102.53	0.65	54	100.53	0.88	18	109.68	6.06	35	101.64	-2.63
4.0	44	99.52	2.08	*55*	*105.49*	*2.96*	76	102.62	2.09	26	108.34	-1.34	*25*	*104.05*	*2.41*
4.5	19	102.75	3.23	57	105.57	0.08	39	102.78	0.16	32	111.00	2.66	19	105.08	1.03
5.0	17	102.15	-0.60	67	107.27	1.70	42	104.21	1.43	41	111.74	0.74	12	106.55	1.47
5.5	11	101.92	-0.23	54	110.41	3.14	23	106.99	2.78	52	111.07	-0.67	8	104.29	-2.26
6.0	3	109.75	7.83	48	109.94	-0.47	21	108.35	1.36	*73*	*114.26*	*3.19*	7	108.50	4.21
6.5	3	105.82	-3.93	32	111.61	1.67	12	107.20	-1.15	62	113.74	-0.52	4	110.54	2.04
7.0	2	101.40	-4.42	30	112.85	1.24	7	108.34	1.14	50	116.34	2.60	1	96.44	-14.10
7.5				21	114.57	1.72				52	116.99	0.65			
8.0				16	114.42	-0.15				35	116.21	-0.78			
8.5				7	116.84	2.42				12	121.48	5.27			
9.0				4	116.72	-0.12				11	120.63	-0.85			
9.5										10	124.53	3.90			
10.0										3	127.81	3.28			
10.5										2	125.42	-2.39			
11.0										1	120.04	-5.38			
Group:	1,463	89.82	1.29	607	105.80	1.35	519	100.64	1.16	490	114.02	1.25	129	103.65	0.51
Relevant:			1.36			1.48			1.29			1.40			0.57

Remark: *n* - number of cases
x - average ball width (W7)
Relevant - length sizes falling into the range providing 90% coverage in length



Shoe last bottom patterns

Ball girth of CHILDREN shoe lasts

Group	English size	Width groups 1	2	3	4	5	6	7	8	9	10	11	12
		A	B	C	D	E	F	G	H	I	J	K	L
I	4	94.5	100.5	106.5	112.5	118.5	124.5	130.5	136.5	142.5	148.5	154.5	160.5
	4½	97.0	103.0	109.0	115.0	121.0	127.0	133.0	139.0	145.0	151.0	157.0	163.0
	5	99.5	105.5	111.5	117.5	123.5	129.5	135.5	141.5	147.5	153.5	159.5	165.5
	5½	102.0	108.0	114.0	120.0	126.0	132.0	138.0	144.0	150.0	156.0	162.0	168.0
	6	104.5	110.5	116.5	122.5	128.5	134.5	140.5	146.5	152.5	158.5	164.5	170.5
	6½	107.0	113.0	119.0	125.0	131.0	137.0	143.0	149.0	155.0	161.0	167.0	173.0
	7	109.5	115.5	121.5	127.5	133.5	139.5	145.5	151.5	157.5	163.5	169.5	175.5
	7½	112.0	118.0	124.0	130.0	136.0	142.0	148.0	154.0	160.0	166.0	172.0	178.0
	8	114.5	120.5	126.5	132.5	138.5	144.5	150.5	156.5	162.5	168.5	174.5	180.5
	8½	117.0	123.0	129.0	135.0	141.0	147.0	153.0	159.0	165.0	171.0	177.0	183.0
	9	119.5	125.5	131.5	137.5	143.5	149.5	155.5	161.5	167.5	173.5	179.5	185.5
	9½	122.0	128.0	134.0	140.0	146.0	152.0	158.0	164.0	170.0	176.0	182.0	188.0
	10	124.5	130.5	136.5	142.5	148.5	154.5	160.5	166.5	172.5	178.5	184.5	190.5
	10½	127.0	133.0	139.0	145.0	151.0	157.0	163.0	169.0	175.0	181.0	187.0	193.0
	11	129.5	135.5	141.5	147.5	153.5	159.5	165.5	171.5	177.5	183.5	189.5	195.5
	11½	132.0	138.0	144.0	150.0	156.0	162.0	168.0	174.0	180.0	186.0	192.0	198.0
	12	134.5	140.5	146.5	152.5	158.5	164.5	170.5	176.5	182.5	188.5	194.5	200.5
	12½	137.0	143.0	149.0	155.0	161.0	167.0	173.0	179.0	185.0	191.0	197.0	203.0
	13	139.5	145.5	151.5	157.5	163.5	169.5	175.5	181.5	187.5	193.5	199.5	205.5
II	½	142.0	148.0	154.0	160.0	166.0	**172.0**	178.0	184.0	190.0	196.0	202.0	208.0
	1	144.5	150.5	156.5	162.5	168.5	174.5	180.5	186.5	192.5	198.5	204.5	210.5
	1½	147.0	153.0	159.0	165.0	171.0	177.0	183.0	189.0	195.0	201.0	207.0	213.0
	2	149.5	155.5	161.5	167.5	173.5	179.5	185.5	191.5	197.5	203.5	209.5	215.5
	2½	152.0	158.0	164.0	170.0	176.0	182.0	188.0	194.0	200.0	206.0	212.0	218.0
	3	154.5	160.5	166.5	172.5	178.5	184.5	190.5	196.5	202.5	208.5	214.5	220.5
	3½	157.0	163.0	169.0	175.0	181.0	187.0	193.0	199.0	205.0	211.0	217.0	223.0
	4	159.5	165.5	171.5	177.5	183.5	189.5	195.5	201.5	207.5	213.5	219.5	225.5
	4½	162.0	168.0	174.0	180.0	186.0	192.0	198.0	204.0	210.0	216.0	222.0	228.0
	5	164.5	170.5	176.5	182.5	188.5	194.5	200.5	206.5	212.5	218.5	224.5	230.5
	5½	167.0	173.0	179.0	185.0	191.0	197.0	203.0	209.0	215.0	221.0	227.0	233.0
	6	169.5	175.5	181.5	187.5	193.5	199.5	205.5	211.5	217.5	223.5	229.5	235.5
	6½	172.0	178.0	184.0	190.0	196.0	202.0	208.0	214.0	220.0	226.0	232.0	238.0
	7	174.5	180.5	186.5	192.5	198.5	204.5	210.5	216.5	222.5	228.5	234.5	240.5
	7½	177.0	183.0	189.0	195.0	201.0	207.0	213.0	219.0	225.0	231.0	237.0	243.0
	8	179.5	185.5	191.5	197.5	203.5	209.5	215.5	221.5	227.5	233.5	239.5	245.5
	8½	182.0	188.0	194.0	200.0	206.0	212.0	218.0	224.0	230.0	236.0	242.0	248.0
	9	184.5	190.5	196.5	202.5	208.5	214.5	220.5	226.5	232.5	238.5	244.5	250.5

Ball girth of BOYS shoe lasts

Group	English	Width groups											
		1	2	3	4	5	**6**	7	8	9	10	11	12
	size	A	B	C	D	E	F	G	H	I	J	K	L
I	9½	146.0	152.0	158.0	164.0	170.0	176.0	182.0	188.0	194.0	200.0	206.0	212.0
	10	147.5	153.5	159.5	165.5	171.5	177.5	183.5	189.5	195.5	201.5	207.5	213.5
	10½	149.0	155.0	161.0	167.0	173.0	179.0	185.0	191.0	197.0	203.0	209.0	215.0
	11	150.5	156.5	162.5	168.5	174.5	180.5	186.5	192.5	198.5	204.5	210.5	216.5
	11½	152.0	158.0	164.0	170.0	176.0	182.0	188.0	194.0	200.0	206.0	212.0	218.0
	12	153.5	159.5	165.5	171.5	177.5	183.5	189.5	195.5	201.5	207.5	213.5	219.5
	12½	155.0	161.0	167.0	173.0	179.0	185.0	191.0	197.0	203.0	209.0	215.0	221.0
	13	156.5	162.5	168.5	174.5	180.5	186.5	192.5	198.5	204.5	210.5	216.5	222.5
II	½	158.0	164.0	170.0	176.0	182.0	188.0	194.0	200.0	206.0	212.0	218.0	224.0
	1	159.5	165.5	171.5	177.5	183.5	189.5	195.5	201.5	207.5	213.5	219.5	225.5
	1½	161.0	167.0	173.0	179.0	185.0	191.0	197.0	203.0	209.0	215.0	221.0	227.0
	2	162.5	168.5	174.5	180.5	186.5	192.5	198.5	204.5	210.5	216.5	222.5	228.5
	2½	164.0	170.0	176.0	182.0	188.0	194.0	200.0	206.0	212.0	218.0	224.0	230.0
	3	165.5	171.5	177.5	183.5	189.5	195.5	201.5	207.5	213.5	219.5	225.5	231.5
	3½	167.0	173.0	179.0	185.0	191.0	197.0	203.0	209.0	215.0	221.0	227.0	233.0
	4	186.5	188.0	189.5	191.0	192.5	198.5	204.5	210.5	216.5	222.5	228.5	234.5
	4½	170.0	176.0	182.0	188.0	194.0	**200.0**	206.0	212.0	218.0	224.0	230.0	236.0
	5	171.5	177.5	183.5	189.5	195.5	201.5	207.5	213.5	219.5	225.5	231.5	237.5
	5½	173.0	179.0	185.0	191.0	197.0	203.0	209.0	215.0	221.0	227.0	233.0	239.0
	6	174.5	180.5	186.5	192.5	198.5	204.5	210.5	216.5	222.5	228.5	234.5	240.5
	6½	176.0	182.0	188.0	194.0	200.0	206.0	212.0	218.0	224.0	230.0	236.0	242.0
	7	177.5	183.5	189.5	195.5	201.5	207.5	213.5	219.5	225.5	231.5	237.5	243.5
	7½	179.0	185.0	191.0	197.0	203.0	209.0	215.0	221.0	227.0	233.0	239.0	245.0
	8	180.5	186.5	192.5	198.5	204.5	210.5	216.5	222.5	228.5	234.5	240.5	246.5
	8½	182.0	188.0	194.0	200.0	206.0	212.0	218.0	224.0	230.0	236.0	242.0	248.0
	9	183.5	189.5	195.5	201.5	207.5	213.5	219.5	225.5	231.5	237.5	243.5	249.5
	9½	185.0	191.0	197.0	203.0	209.0	215.0	221.0	227.0	233.0	239.0	245.0	251.0
	10	186.5	192.5	198.5	204.5	210.5	216.5	222.5	228.5	234.5	240.5	246.5	252.5
	10½	188.0	194.0	200.0	206.0	212.0	218.0	224.0	230.0	236.0	242.0	248.0	254.0
	11	189.5	195.5	201.5	207.5	213.5	219.5	225.5	231.5	237.5	243.5	249.5	255.5
	11½	191.0	197.0	203.0	209.0	215.0	221.0	227.0	233.0	239.0	245.0	251.0	257.0
	12	192.5	198.5	204.5	210.5	216.5	222.5	228.5	234.5	240.5	246.5	252.5	258.5
	12½	194.0	200.0	206.0	212.0	218.0	224.0	230.0	236.0	242.0	248.0	254.0	260.0
	13	195.5	201.5	207.5	213.5	219.5	225.5	231.5	237.5	243.5	249.5	255.5	261.5
	13½	197.0	203.0	209.0	215.0	221.0	227.0	233.0	239.0	245.0	251.0	257.0	263.0

Ball girth of GIRLS shoe lasts

French point	Width groups											
	1	2	3	4	5	**6**	7	8	9	10	11	12
27	139.5	145.5	151.5	157.5	163.5	169.5	175.5	181.5	187.5	193.5	199.5	205.5
28	142.0	148.0	154.0	160.0	166.0	172.0	178.0	184.0	190.0	196.0	202.0	208.0
29	144.5	150.5	156.5	162.5	168.5	174.5	180.5	186.5	192.5	198.5	204.5	210.5
30	147.0	153.0	159.0	165.0	171.0	177.0	183.0	189.0	195.0	201.0	207.0	213.0
31	149.5	155.5	161.5	167.5	173.5	179.5	185.5	191.5	197.5	203.5	209.5	215.5
32	152.0	158.0	164.0	170.0	176.0	182.0	188.0	194.0	200.0	206.0	212.0	218.0
33	154.5	160.5	166.5	172.5	178.5	184.5	190.5	196.5	202.5	208.5	214.5	220.5
34	157.0	163.0	169.0	175.0	181.0	187.0	193.0	199.0	205.0	211.0	217.0	223.0
35	159.5	165.5	171.5	177.5	183.5	189.5	195.5	201.5	207.5	213.5	219.5	225.5
36	162.0	168.0	174.0	180.0	186.0	**192.0**	198.0	204.0	210.0	216.0	222.0	228.0
37	164.5	170.5	176.5	182.5	188.5	194.5	200.5	206.5	212.5	218.5	224.5	230.5
38	167.0	173.0	179.0	185.0	191.0	197.0	203.0	209.0	215.0	221.0	227.0	233.0
39	169.5	175.5	181.5	187.5	193.5	199.5	205.5	211.5	217.5	223.5	229.5	235.5
40	172.0	178.0	184.0	190.0	196.0	202.0	208.0	214.0	220.0	226.0	232.0	238.0
41	174.5	180.5	186.5	192.5	198.5	204.5	210.5	216.5	222.5	228.5	234.5	240.5
42	177.0	183.0	189.0	195.0	201.0	207.0	213.0	219.0	225.0	231.0	237.0	243.0
43	179.5	185.5	191.5	197.5	203.5	209.5	215.5	221.5	227.5	233.5	239.5	245.5
44	182.0	188.0	194.0	200.0	206.0	212.0	218.0	224.0	230.0	236.0	242.0	248.0
45	184.5	190.5	196.5	202.5	208.5	214.5	220.5	226.5	232.5	238.5	244.5	250.5
46	187.0	193.0	199.0	205.0	211.0	217.0	223.0	229.0	235.0	241.0	247.0	253.0

Annex K-1.4

Ball girth of MEN shoe lasts

Group	English size	Width groups											
		1	2	3	4	5	**6**	7	8	9	10	11	12
		A	B	C	D	E	F	G	H	I	J	K	L
I	12½	142.5	150.5	158.5	166.5	174.5	182.5	190.5	198.5	206.5	214.5	222.5	230.5
	13	145.0	153.0	161.0	169.0	177.0	185.0	193.0	201.0	209.0	217.0	225.0	233.0
II	½	147.5	155.5	163.5	171.5	179.5	187.5	195.5	203.5	211.5	219.5	227.5	235.5
	1	150.0	158.0	166.0	174.0	182.0	190.0	198.0	206.0	214.0	222.0	230.0	238.0
	1½	152.5	160.5	168.5	176.5	184.5	192.5	200.5	208.5	216.5	224.5	232.5	240.5
	2	155.0	163.0	171.0	179.0	187.0	195.0	203.0	211.0	219.0	227.0	235.0	243.0
	2½	157.5	165.5	173.5	181.5	189.5	197.5	205.5	213.5	221.5	229.5	237.5	245.5
	3	160.0	168.0	176.0	184.0	192.0	200.0	208.0	216.0	224.0	232.0	240.0	248.0
	3½	162.5	170.5	178.5	186.5	194.5	202.5	210.5	218.5	226.5	234.5	242.5	250.5
	4	165.0	173.0	181.0	189.0	197.0	205.0	213.0	221.0	229.0	237.0	245.0	253.0
	4½	167.5	175.5	183.5	191.5	199.5	207.5	215.5	223.5	231.5	239.5	247.5	255.5
	5	170.0	178.0	186.0	194.0	202.0	210.0	218.0	226.0	234.0	242.0	250.0	258.0
	5½	172.5	180.5	188.5	196.5	204.5	212.5	220.5	228.5	236.5	244.5	252.5	260.5
	6	175.0	183.0	191.0	199.0	207.0	**215.0**	223.0	231.0	239.0	247.0	255.0	263.0
	6½	177.5	185.5	193.5	201.5	209.5	217.5	225.5	233.5	241.5	249.5	257.5	265.5
	7	180.0	188.0	196.0	204.0	212.0	220.0	228.0	236.0	244.0	252.0	260.0	268.0
	7½	182.5	190.5	198.5	206.5	214.5	222.5	230.5	238.5	246.5	254.5	262.5	270.5
	8	185.0	193.0	201.0	209.0	217.0	225.0	233.0	241.0	249.0	257.0	265.0	273.0
	8½	187.5	195.5	203.5	211.5	219.5	227.5	235.5	243.5	251.5	259.5	267.5	275.5
	9	190.0	198.0	206.0	214.0	222.0	230.0	238.0	246.0	254.0	262.0	270.0	278.0
	9½	192.5	200.5	208.5	216.5	224.5	232.5	240.5	248.5	256.5	264.5	272.5	280.5
	10	195.0	203.0	211.0	219.0	227.0	235.0	243.0	251.0	259.0	267.0	275.0	283.0
	10½	197.5	205.5	213.5	221.5	229.5	237.5	245.5	253.5	261.5	269.5	277.5	285.5
	11	200.0	208.0	216.0	224.0	232.0	240.0	248.0	256.0	264.0	272.0	280.0	288.0
	11½	202.5	210.5	218.5	226.5	234.5	242.5	250.5	258.5	266.5	274.5	282.5	290.5
	12	205.0	213.0	221.0	229.0	237.0	245.0	253.0	261.0	269.0	277.0	285.0	293.0
	12½	207.5	215.5	223.5	231.5	239.5	247.5	255.5	263.5	271.5	279.5	287.5	295.5
	13	210.0	218.0	226.0	234.0	242.0	250.0	258.0	266.0	274.0	282.0	290.0	298.0

Ball girth of MEN shoe lasts

Group	English size	Width groups											
		1	2	3	4	5	6	7	8	9	10	11	12
		A	B	C	D	E	F	G	H	I	J	K	L
I	12½	142.5	150.5	158.5	166.5	174.5	182.5	190.5	198.5	206.5	214.5	222.5	230.5
	13	145.0	153.0	161.0	169.0	177.0	185.0	193.0	201.0	209.0	217.0	225.0	233.0
II	½	147.5	155.5	163.5	171.5	179.5	187.5	195.5	203.5	211.5	219.5	227.5	235.5
	1	150.0	158.0	166.0	174.0	182.0	190.0	198.0	206.0	214.0	222.0	230.0	238.0
	1½	152.5	160.5	168.5	176.5	184.5	192.5	200.5	208.5	216.5	224.5	232.5	240.5
	2	155.0	163.0	171.0	179.0	187.0	195.0	203.0	211.0	219.0	227.0	235.0	243.0
	2½	157.5	165.5	173.5	181.5	189.5	197.5	205.5	213.5	221.5	229.5	237.5	245.5
	3	160.0	168.0	176.0	184.0	192.0	200.0	208.0	216.0	224.0	232.0	240.0	248.0
	3½	162.5	170.5	178.5	186.5	194.5	202.5	210.5	218.5	226.5	234.5	242.5	250.5
	4	165.0	173.0	181.0	189.0	197.0	205.0	213.0	221.0	229.0	237.0	245.0	253.0
	4½	167.5	175.5	183.5	191.5	199.5	207.5	215.5	223.5	231.5	239.5	247.5	255.5
	5	170.0	178.0	186.0	194.0	202.0	210.0	218.0	226.0	234.0	242.0	250.0	258.0
	5½	172.5	180.5	188.5	196.5	204.5	212.5	220.5	228.5	236.5	244.5	252.5	260.5
	6	175.0	183.0	191.0	199.0	207.0	**215.0**	223.0	231.0	239.0	247.0	255.0	263.0
	6½	177.5	185.5	193.5	201.5	209.5	217.5	225.5	233.5	241.5	249.5	257.5	265.5
	7	180.0	188.0	196.0	204.0	212.0	220.0	228.0	236.0	244.0	252.0	260.0	268.0
	7½	182.5	190.5	198.5	206.5	214.5	222.5	230.5	238.5	246.5	254.5	262.5	270.5
	8	185.0	193.0	201.0	209.0	217.0	225.0	233.0	241.0	249.0	257.0	265.0	273.0
	8½	187.5	195.5	203.5	211.5	219.5	227.5	235.5	243.5	251.5	259.5	267.5	275.5
	9	190.0	198.0	206.0	214.0	222.0	230.0	238.0	246.0	254.0	262.0	270.0	278.0
	9½	192.5	200.5	208.5	216.5	224.5	232.5	240.5	248.5	256.5	264.5	272.5	280.5
	10	195.0	203.0	211.0	219.0	227.0	235.0	243.0	251.0	259.0	267.0	275.0	283.0
	10½	197.5	205.5	213.5	221.5	229.5	237.5	245.5	253.5	261.5	269.5	277.5	285.5
	11	200.0	208.0	216.0	224.0	232.0	240.0	248.0	256.0	264.0	272.0	280.0	288.0
	11½	202.5	210.5	218.5	226.5	234.5	242.5	250.5	258.5	266.5	274.5	282.5	290.5
	12	205.0	213.0	221.0	229.0	237.0	245.0	253.0	261.0	269.0	277.0	285.0	293.0
	12½	207.5	215.5	223.5	231.5	239.5	247.5	255.5	263.5	271.5	279.5	287.5	295.5
	13	210.0	218.0	226.0	234.0	242.0	250.0	258.0	266.0	274.0	282.0	290.0	298.0

Ball girth of WOMEN shoe lasts

French	Width groups											
point	1	2	3	4	5	**6**	7	8	9	10	11	12
32	140.0	148.0	156.0	164.0	172.0	180.0	188.0	196.0	204.0	212.0	220.0	228.0
33	144.0	152.0	160.0	168.0	176.0	184.0	192.0	200.0	208.0	216.0	224.0	232.0
34	148.0	156.0	164.0	172.0	180.0	188.0	196.0	204.0	212.0	220.0	228.0	236.0
35	152.0	160.0	168.0	176.0	184.0	192.0	200.0	208.0	216.0	224.0	232.0	240.0
36	156.0	164.0	172.0	180.0	188.0	196.0	204.0	212.0	220.0	228.0	236.0	244.0
37	160.0	168.0	176.0	184.0	192.0	**200.0**	208.0	216.0	224.0	232.0	240.0	248.0
38	164.0	172.0	180.0	188.0	196.0	204.0	212.0	220.0	228.0	236.0	244.0	252.0
39	168.0	176.0	184.0	192.0	200.0	208.0	216.0	224.0	232.0	240.0	248.0	256.0
40	172.0	180.0	188.0	196.0	204.0	212.0	220.0	228.0	236.0	244.0	252.0	260.0
41	176.0	184.0	192.0	200.0	208.0	216.0	224.0	232.0	240.0	248.0	256.0	264.0
42	180.0	188.0	196.0	204.0	212.0	220.0	228.0	236.0	244.0	252.0	260.0	268.0
43	184.0	192.0	200.0	208.0	216.0	224.0	232.0	240.0	248.0	256.0	264.0	272.0
44	188.0	196.0	204.0	212.0	220.0	228.0	236.0	244.0	252.0	260.0	268.0	276.0

Ball girth of CHILDREN shoe lasts

French point	Width groups											
	1	2	3	4	5	**6**	7	8	9	10	11	12
18	86.0	92.0	98.0	104.0	110.0	116.0	122.0	128.0	134.0	140.0	146.0	152.0
19	90.0	96.0	102.0	108.0	114.0	120.0	126.0	132.0	138.0	144.0	150.0	156.0
20	94.0	100.0	106.0	112.0	118.0	124.0	130.0	136.0	142.0	148.0	154.0	160.0
21	98.0	104.0	110.0	116.0	122.0	128.0	134.0	140.0	146.0	152.0	158.0	164.0
22	102.0	108.0	114.0	120.0	126.0	132.0	138.0	144.0	150.0	156.0	162.0	168.0
23	106.0	112.0	118.0	124.0	130.0	136.0	142.0	148.0	154.0	160.0	166.0	172.0
24	110.0	116.0	122.0	128.0	134.0	140.0	146.0	152.0	158.0	164.0	170.0	176.0
25	114.0	120.0	126.0	132.0	138.0	144.0	150.0	156.0	162.0	168.0	174.0	180.0
26	118.0	124.0	130.0	136.0	142.0	148.0	154.0	160.0	166.0	172.0	178.0	184.0
27	122.0	128.0	134.0	140.0	146.0	152.0	158.0	164.0	170.0	176.0	182.0	188.0
28	126.0	132.0	138.0	144.0	150.0	156.0	162.0	168.0	174.0	180.0	186.0	192.0
29	130.0	136.0	142.0	148.0	154.0	160.0	166.0	172.0	178.0	184.0	190.0	196.0
30	134.0	140.0	146.0	152.0	158.0	164.0	170.0	176.0	182.0	188.0	194.0	200.0
31	138.0	144.0	150.0	156.0	162.0	168.0	174.0	180.0	186.0	192.0	198.0	204.0
32	142.0	148.0	154.0	160.0	166.0	**172.0**	178.0	184.0	190.0	196.0	202.0	208.0
33	146.0	152.0	158.0	164.0	170.0	176.0	182.0	188.0	194.0	200.0	206.0	212.0
34	150.0	156.0	162.0	168.0	174.0	180.0	186.0	192.0	198.0	204.0	210.0	216.0
35	154.0	160.0	166.0	172.0	178.0	184.0	190.0	196.0	202.0	208.0	214.0	220.0
36	158.0	164.0	170.0	176.0	182.0	188.0	194.0	200.0	206.0	212.0	218.0	224.0
37	162.0	168.0	174.0	180.0	186.0	192.0	198.0	204.0	210.0	216.0	222.0	228.0
38	166.0	172.0	178.0	184.0	190.0	196.0	202.0	208.0	214.0	220.0	226.0	232.0
39	170.0	176.0	182.0	188.0	194.0	200.0	206.0	212.0	218.0	224.0	230.0	236.0
40	174.0	180.0	186.0	192.0	198.0	204.0	210.0	216.0	222.0	228.0	234.0	240.0
41	178.0	184.0	190.0	196.0	202.0	208.0	214.0	220.0	226.0	232.0	238.0	244.0
42	182.0	188.0	194.0	200.0	206.0	212.0	218.0	224.0	230.0	236.0	242.0	248.0
43	186.0	192.0	198.0	204.0	210.0	216.0	222.0	228.0	234.0	240.0	246.0	252.0
44	190.0	196.0	202.0	208.0	214.0	220.0	226.0	232.0	238.0	244.0	250.0	256.0
45	194.0	200.0	206.0	212.0	218.0	224.0	230.0	236.0	242.0	248.0	254.0	260.0
46	198.0	204.0	210.0	216.0	222.0	228.0	234.0	240.0	246.0	252.0	258.0	264.0
47	202.0	208.0	214.0	220.0	226.0	232.0	238.0	244.0	250.0	256.0	262.0	268.0

Ball girth of BOYS shoe lasts

French	Width groups											
point	1	2	3	4	5	**6**	7	8	9	10	11	12
27	142.5	148.5	154.5	160.5	166.5	172.5	178.5	184.5	190.5	196.5	202.5	208.5
28	145.0	151.0	157.0	163.0	169.0	175.0	181.0	187.0	193.0	199.0	205.0	211.0
29	147.5	153.5	159.5	165.5	171.5	177.5	183.5	189.5	195.5	201.5	207.5	213.5
30	150.0	156.0	162.0	168.0	174.0	180.0	186.0	192.0	198.0	204.0	210.0	216.0
31	152.5	158.5	164.5	170.5	176.5	182.5	188.5	194.5	200.5	206.5	212.5	218.5
32	155.0	161.0	167.0	173.0	179.0	185.0	191.0	197.0	203.0	209.0	215.0	221.0
33	157.5	163.5	169.5	175.5	181.5	187.5	193.5	199.5	205.5	211.5	217.5	223.5
34	160.0	166.0	172.0	178.0	184.0	190.0	196.0	202.0	208.0	214.0	220.0	226.0
35	162.5	168.5	174.5	180.5	186.5	192.5	198.5	204.5	210.5	216.5	222.5	228.5
36	165.0	171.0	177.0	183.0	189.0	195.0	201.0	207.0	213.0	219.0	225.0	231.0
37	167.5	173.5	179.5	185.5	191.5	197.5	203.5	209.5	215.5	221.5	227.5	233.5
38	170.0	176.0	182.0	188.0	194.0	**200.0**	206.0	212.0	218.0	224.0	230.0	236.0
39	172.5	178.5	184.5	190.5	196.5	202.5	208.5	214.5	220.5	226.5	232.5	238.5
40	175.0	181.0	187.0	193.0	199.0	205.0	211.0	217.0	223.0	229.0	235.0	241.0
41	177.5	183.5	189.5	195.5	201.5	207.5	213.5	219.5	225.5	231.5	237.5	243.5
42	180.0	186.0	192.0	198.0	204.0	210.0	216.0	222.0	228.0	234.0	240.0	246.0
43	182.5	188.5	194.5	200.5	206.5	212.5	218.5	224.5	230.5	236.5	242.5	248.5
44	185.0	191.0	197.0	203.0	209.0	215.0	221.0	227.0	233.0	239.0	245.0	251.0
45	187.5	193.5	199.5	205.5	211.5	217.5	223.5	229.5	235.5	241.5	247.5	253.5
46	190.0	196.0	202.0	208.0	214.0	220.0	226.0	232.0	238.0	244.0	250.0	256.0
47	192.5	198.5	204.5	210.5	216.5	222.5	228.5	234.5	240.5	246.5	252.5	258.5
48	195.0	201.0	207.0	213.0	219.0	225.0	231.0	237.0	243.0	249.0	255.0	261.0
49	197.5	203.5	209.5	215.5	221.5	227.5	233.5	239.5	245.5	251.5	257.5	263.5

Ball girth of GIRLS shoe lasts

French point	Width groups											
	1	2	3	4	5	**6**	7	8	9	10	11	12
27	139.5	145.5	151.5	157.5	163.5	169.5	175.5	181.5	187.5	193.5	199.5	205.5
28	142.0	148.0	154.0	160.0	166.0	172.0	178.0	184.0	190.0	196.0	202.0	208.0
29	144.5	150.5	156.5	162.5	168.5	174.5	180.5	186.5	192.5	198.5	204.5	210.5
30	147.0	153.0	159.0	165.0	171.0	177.0	183.0	189.0	195.0	201.0	207.0	213.0
31	149.5	155.5	161.5	167.5	173.5	179.5	185.5	191.5	197.5	203.5	209.5	215.5
32	152.0	158.0	164.0	170.0	176.0	182.0	188.0	194.0	200.0	206.0	212.0	218.0
33	154.5	160.5	166.5	172.5	178.5	184.5	190.5	196.5	202.5	208.5	214.5	220.5
34	157.0	163.0	169.0	175.0	181.0	187.0	193.0	199.0	205.0	211.0	217.0	223.0
35	159.5	165.5	171.5	177.5	183.5	189.5	195.5	201.5	207.5	213.5	219.5	225.5
36	162.0	168.0	174.0	180.0	186.0	**192.0**	198.0	204.0	210.0	216.0	222.0	228.0
37	164.5	170.5	176.5	182.5	188.5	194.5	200.5	206.5	212.5	218.5	224.5	230.5
38	167.0	173.0	179.0	185.0	191.0	197.0	203.0	209.0	215.0	221.0	227.0	233.0
39	169.5	175.5	181.5	187.5	193.5	199.5	205.5	211.5	217.5	223.5	229.5	235.5
40	172.0	178.0	184.0	190.0	196.0	202.0	208.0	214.0	220.0	226.0	232.0	238.0
41	174.5	180.5	186.5	192.5	198.5	204.5	210.5	216.5	222.5	228.5	234.5	240.5
42	177.0	183.0	189.0	195.0	201.0	207.0	213.0	219.0	225.0	231.0	237.0	243.0
43	179.5	185.5	191.5	197.5	203.5	209.5	215.5	221.5	227.5	233.5	239.5	245.5
44	182.0	188.0	194.0	200.0	206.0	212.0	218.0	224.0	230.0	236.0	242.0	248.0
45	184.5	190.5	196.5	202.5	208.5	214.5	220.5	226.5	232.5	238.5	244.5	250.5
46	187.0	193.0	199.0	205.0	211.0	217.0	223.0	229.0	235.0	241.0	247.0	253.0

Ball girth of MEN shoe lasts

French point	Width groups											
	1	2	3	4	5	**6**	7	8	9	10	11	12
31	143.0	151.0	159.0	167.0	175.0	183.0	191.0	199.0	207.0	215.0	223.0	231.0
32	147.0	155.0	163.0	171.0	179.0	187.0	195.0	203.0	211.0	219.0	227.0	235.0
33	151.0	159.0	167.0	175.0	183.0	191.0	199.0	207.0	215.0	223.0	231.0	239.0
34	155.0	163.0	171.0	179.0	187.0	195.0	203.0	211.0	219.0	227.0	235.0	243.0
35	159.0	167.0	175.0	183.0	191.0	199.0	207.0	215.0	223.0	231.0	239.0	247.0
36	163.0	171.0	179.0	187.0	195.0	203.0	211.0	219.0	227.0	235.0	243.0	251.0
37	167.0	175.0	183.0	191.0	199.0	207.0	215.0	223.0	231.0	239.0	247.0	255.0
38	171.0	179.0	187.0	195.0	203.0	211.0	219.0	227.0	235.0	243.0	251.0	259.0
39	175.0	183.0	191.0	199.0	207.0	**215.0**	223.0	231.0	239.0	247.0	255.0	263.0
40	179.0	187.0	195.0	203.0	211.0	219.0	227.0	235.0	243.0	251.0	259.0	267.0
41	183.0	191.0	199.0	207.0	215.0	223.0	231.0	239.0	247.0	255.0	263.0	271.0
42	187.0	195.0	203.0	211.0	219.0	227.0	235.0	243.0	251.0	259.0	267.0	275.0
43	191.0	199.0	207.0	215.0	223.0	231.0	239.0	247.0	255.0	263.0	271.0	279.0
44	195.0	203.0	211.0	219.0	227.0	235.0	243.0	251.0	259.0	267.0	275.0	283.0
45	199.0	207.0	215.0	223.0	231.0	239.0	247.0	255.0	263.0	271.0	279.0	287.0
46	203.0	211.0	219.0	227.0	235.0	243.0	251.0	259.0	267.0	275.0	283.0	291.0
47	207.0	215.0	223.0	231.0	239.0	247.0	255.0	263.0	271.0	279.0	287.0	295.0
48	211.0	219.0	227.0	235.0	243.0	251.0	259.0	267.0	275.0	283.0	291.0	299.0
49	215.0	223.0	231.0	239.0	247.0	255.0	263.0	271.0	279.0	287.0	295.0	303.0