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Developing a scientific approach towards design and manufacture of Indian men's work place casual footwear

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Abstract
Due to the lack of Indian sizing surveys, footwear manufacturers are forced to use the size charts of other countries where the anthropometric make of the population is very different from that of India. This results in manufacturing of a product which might not fit the Indian feet types. A research proposal has been submitted wherein parameters of lasts of five styles of existing Indian men's work place casual footwear would be measured and compared against the appropriate Bureau of Indian Standards guidelines. Thereafter, identified anthropometric measurements of feet of Indian office going men would be measured, computed and based on analysis of the results, requirement of unique lasts for different ethnic groups in the population would be ascertained. Based on the parameters proposed through the report submitted to UNIDO, lasts for mode sizes would be constructed for five styles of Indian men's work place casual footwear and pairs of shoes would be constructed on the redesigned lasts and SATRA Footwear Comfort Index would be computed along with assessment of long term comfort using EMED pressure measuring insole checking for even pressure distribution at the plantar surface of the foot while walking on treadmill at a specified speed, using peak pressure, pressure - time integral and maximal area and other variables in data analysis, as well as SATRA dynamic shock absorption. Thus the core objective of the proposal is to improve the satisfaction of Indian men while wearing work place casual footwear. The findings would lead to a scientific approach towards design and manufacture of work place casual men's footwear in India, which in turn would contribute to better fit, comfort and consumer satisfaction.

Keywords: feet, sizing, last assessment, forefoot shapes, anthropometric measurements, fit, Indian men's work place casual footwear, long term comfort

1. Introduction
Feet is one of the most important parts of the human body without them one would not be able to carry himself/ herself throughout the day. In Ayurveda (traditional Hindu system of spiritual medicine), foot is considered as an important motor organ. (http://www.ayurvedictalk.com/padabhyanga-foot-massage-the-mother-of-all-ayurvedic-therapies/2659/).
Serving as an interface between the foot and the ground, footwear is expected to be designed to protect the foot from undesirable pressure stimulus and facilitate it to perform its daily functions. However the induced foot deformities from ill-fitting footwear have been reported to be the major causes for discomfort, pain and even foot problems such as calluses, corns, hallux valguses, plantar ulcers and pressure sores. Therefore a pair of shoes designed and manufactured with a good fit is very important for foot comfort and health. (Xiong, Zhao, Jiang, & Dong, 2010) [25],
The most important component of the shoemaking is a shoe last, a solid three dimensional mould around which a shoe is made. Figure 1 shows the close relationship between a shoe, a shoe last, and the foot. A shoe last is closely related to the foot and its design is based on many factors such as the foot shape/size, comfort parameters, shoe fashion/style, type of construction, etc. It has been regarded as the 'heart' of shoemaking since it mainly determines the shoe shape, fashion, fit, and comfort qualities. The back part of the shoe last is for fit and comfort, while the toe part (pointed toe, rounded toe, squared toe, etc.) is mainly for fashion and style. (Xiong & Jiang, 2010) [25].

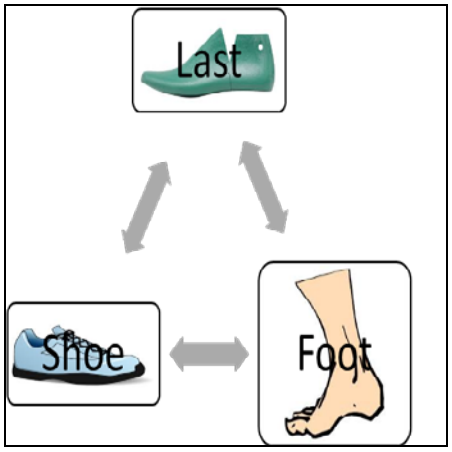


Fig 1: Foot, shoe, last triangle

Lasts are made of either wood, plastic (High Density

Polyethylene/ Low Density Polyethylene) or metal.
The major differences between last and foot are:
The foot cannot be said to have a single shape: this varies in different positions when sitting, standing and walking. The last surface is then smoothed in contrast to the bumpy foot shape (e.g. the toes). Additionally, after a particular dimension of the foot is measured, this actual measurement is not always reproduced on the corresponding last. Sometimes the last is made deliberately larger or smaller, and these 'last allowance' (dimensional differences) are normally according to facts and the last-maker's experience. For example, the last is made longer than the foot to accommodate the foot extension during weight-bearing and walking. The last girth can be made smaller to prevent the foot from slipping forward in case of adults. (Chien-Chung, 1993) [5]
The last also has a sharp edge or feather edge which divides the upper and bottom part, for ease of lasting, which is one of the operations in footwear construction. Moreover the last has a higher and narrower instep or cone as against rounded form of foot for ease of entry of feet, snugly fitting of foot etc.
Footwear was one of the first manufactured products and footwear making was one of the ancient professions. The primary function of footwear is to protect the sole and upper part of the foot. The secondary function is to support the foot to perform certain unusual tasks and to overcome some abnormalities in the foot itself. (Bata Shoe Company Private Limited)

- The comfort of a given shoe depends on the activity being performed.
- An important factor for the shoe comfort was the fit of the shoe. (Miller, Nigg, Liu, Stefanyshyn, & Mathew, 2000) [15]

Many people speak of shoe comfort but the meaning of this is quite difficult, because shoe fit itself is a subjective judgement of the consumer's feeling. From the point of view of fit, there is a common belief that if the shoe fits correctly, comfort automatically follows. However, this is not necessarily true, as shoe comfort involves much more than proper size and fit. To select comfortable footwear, the following factors have always to be considered.

(1) Proper fit: It is obvious that the shoe size must conform to the foot size, not only simply to foot length and joint girth (or width) but also heel to ball length, heel, top line, etc. The proper fit means a correct dimensional mating of foot and shoe throughout the whole shoe.

(2) Flexibility: Shoe flexibility mainly refers to the flex action across the ball. In taking a step, the flexion of the bare foot across the ball is about 50-60 degrees at the maximum angle (Helfet, Lee, & David, 1980) [13]. From the point of view of comfort, the footwear should flex at the ball easily and with the same degree of flexion as the bare foot.

(3) Upper materials: There are some elements of shoe upper materials that determine the shoe comfort i.e., conformability, breathability, shape retention, textile, weight, suppleness and softness.

(4) Construction: Shoe construction determines the structural integrity of the shoe components and its assembly methods. It also determines the retention of the shape (or dimensional) stability of the footwear during wearing.

(5) Under foot resilience: The foot receive an average of 8,000 step-shocks a day (Rossi & Tennant, 1984). A cushioned buffer zone between foot and non-resilient sole or ground brings about a completely different feeling of underfoot comfort.
Both shoe fit and comfort are involved in the functioning of the foot. Obviously, because footwear is made in quantity, its dimensions have been fixed and settled once and for all at the time of manufacture by the shoe last, on which it was made. The foot is just the opposite; it is a very much alive, changing and moving physical part which is connected to other moving parts. The foot is a tool designed for walking. A shoe which, in the standing position may seem to be the right size, shape and fit, may nevertheless during walking fail to provide the expected comfort. The dynamic factors (i.e., tread, gait patterns, perspiration, foot balance and foot injury) can always affect the static factors of fit assessment, causing discomfort. (Chien-Chung, 1993) [5]
A footwear size is an alphanumerical indication of the fitting size of the footwear for a person. (http://images.fibre2fashion.com/ArticleResources/PdfFiles/47/4697.pdf). Often it just consists of a number indicating the length. There are different footwear sizing systems that are used worldwide. These systems differ in

- What they measure
- What unit of measurement they use
- Where the starting size is positioned (American sizes start at one but English sizes start at zero. This is similar to the way that floors in buildings are numbered; the British count the ground floor as zero, whereas the Americans count the ground floor as one).

Few systems, also take the width/girth of the feet into account. Some regions use different footwear size systems for different types of footwear - men, women, children, sports or safety footwear. Each size of footwear is considered suitable for a small interval of foot lengths. The inner cavity of a shoe must typically be 13-20 mm longer than the foot. In order to accommodate variations in foot sizes, alternative width fittings are available. By the use of fittings it is possible to fit greater number of feet more efficiently. The number of fittings used will be governed by the class of trade being catered for.
Footwear has long outgrown in its practical purpose and today is regarded more as a fashion statement than a necessity, particularly with the affluent. The footwear industry occupies a prominent position in the Indian economy in view of its substantial employment potential and growth. The Indian footwear market is valued at rupees six thousand crores. The industry directly employs more than a lakh personnel.
India annually produces 909 million pairs of leather footwear, 100 million pairs of leather footwear uppers and1056 million pairs of non - leather footwear. 94.4% of footwear which includes non - leather footwear produced in India is consumed by the domestic market. 88.6% of leather footwear produced is consumed by the domestic consumers.

In other words more proportion of leather footwear produced in India are exported in comparison to non - leather footwear. Annually 805 million pairs of leather footwear and 1949 million pairs of footwear are consumed by the domestic market. (Sarkar, 2011) [20]. There are nearly 4000 units engaged in manufacturing footwear in India. The industry is dominated by small scale units with the total production of 55%. The total turnover of the footwear industry including leather and non-leather footwear is estimated at ₹. 8500-9500 crores (US $ 127 - 142 crores) including ₹.1200-1400 crores (US $ 18 - 21 crores) in the household segment. India's share in global leather footwear imports is around 1.4%. Leather shoes and uppers are manufactured in medium to large-scale units and the sandals and chappals are manufactured in the household and cottage sector. India produces more of gent's footwear while the world's major production is in ladies footwear. In the case of chappals and sandals, use of non-leather material is prevalent in the domestic market. (http://footwearsinfoline.tripod.com/ind_footwr_industry_overview.htm). In the year 2008, the total consumption was 1,53,20,00,000 pairs. There already are a large number of players, both domestic and international, in the semi-formal, formal and casual segment but the casual segment dominates the Indian footwear market with a 75% share. Branded sportswear is also growing at a faster rate than the other segments and the key players in this segment are Adidas, Reebok, Nike, Puma *Et al*.

The footwear market can also be bifurcated into men, women and kid's footwear segments. Men's footwear occupies the maximum share in the Indian footwear market. The share of men's footwear was estimated to be around 55% in 2012, followed by women's footwear with a share of 30%. Further, kid's footwear was estimated to capture around 15% share in the market in 2012. The footwear industry in India is fragmented into casual footwear, mass footwear, premium and sports footwear. Mass footwear usually refers to low price footwear and majorly consists of slippers. On the other hand, casual footwear involves those preferred by people for daily wear in schools, colleges or workplace etc. Casual footwear dominates the market followed by mass footwear. The share of casual footwear was estimated to be 61% in 2012. However, casual footwear is expected to continue to dominate the market, the share of sports and premium footwear is expected to increase. (G. Anand & Alekya, 2015) [1]

The industry covers a vast spectrum of inputs, activities, skills and products i.e. leather, components, chemicals, last making, uppers, wholesalers and retailing. The footwear industry exist both in traditional and modern sector.

A new method of investigating the relationship between foot shape and shoe last shape was presented by Chien-Chung C. R., in 1993 [5] as part of his PhD thesis submitted to King's College School of Medicine and Dentistry, University of London. This method has been designed by the comparison of volumetric data, surface areas and their derived cross-sectional data from the foot and last

There are only five measurements which can be absolutely coordinated from the foot onto the last surface, i.e., stick length, medial heel to ball length, joint girth, joint width, and seat width. (Chien-Chung, 1993) [5]

The 3D form of a model last serves as the main information base for designing, tooling up and working parts of shoe machines. In its turn, the last design depends on the anatomy of the foot as well as on fashion trends. In general, there is also an absence of uniform approach to the last modelling. However, it is safe to say that traditional techniques of manufacturing the model shoe last assume the development of a set of flat patterns (a bottom pattern of the last, longitudinal vertical section, about nine transverse-vertical cross-sections of the main anatomical points of the foot) for control of the last manufacturing process. The character of a surface between shaping contours is very arbitrary, therefore the complex surface of the last cannot be unequivocally designed. Consequently the received form does not always correspond to the patterns, that has subsequently an effect for tooling-up designing and accuracy of surfaces adjustment. Ultimately, the designer is influenced by a last stock offered by the last manufacturers.The complete range of footwear should be developed on a basis of sufficient results of mass foot measurement. Correct usage of the results of mass foot-sizing when determining the last fittings probably is possible only on the basis of additional information, assumed from detailed researches of the feet. Anatomic structure and physiological foot functions define the pressure rendered on it by the footwear uppers (as it is shown by rheographical research). Last models are not usually made from new but are often adapted from existing models. A specific onscreen methodology of a shoe last design directly from individual anthropometric data was proposed and evaluated by Gordeyeva (1998) [11] as part of Ph. D. thesis submission to De Montfort University. The scope of the study was limited to ladies court shoe lasts, with possibility of application to orthopaedics, prosthetic appliances and sport footwear design.

The top view of the foot is commonly used to match the shoe last outline when customizing footwear. (Goonetilleke & Luximon, 2001) [9]

However, in the traditional shoemaking, the shoe is categorized by the length only (sometimes the length and width) for the customer to select, even though both the shoe and foot are complex 3D objects. Since different people have different foot shapes (wide vs. narrow, slim vs. fat, high-arched vs. low-arched), even though they may have the same foot length, the customers need to learn how to adapt their own feet to the standardized shoes to fit their own needs. For example, the use of different lacing methods in shoes, off-the-shelf insoles, and arch supports to change or adapt a shoe based on their own personal needs. In this procedure, the customer's specific needs are not considered. Often, a customized shoe is needed for the person whose foot shape is not normal or whose feet are very sensitive. Increasingly, there is a trend among the shoe manufacturers to advance the shoe customization so that the customers' satisfaction level and the manufacturer's competitive power can be improved. Xiong *et al*. (2010) [25], proposed an automated system which can make customized shoes in the year 2009. The major features of the CAD system which can be used for designing customized shoe last tailor-made for the customer's foot and the chosen style are as follows.

The input into CAD system begins with the customer's selection of the style (toe style, colour and shoe material combinations, heel height, etc.) from shoe digital database.

Then, the customer's feet will be laser-scanned through a YETI™ foot scanner; this process takes approximately 10 s. The customer can then leave the store and the customized shoes will be delivered to the customer's mail address within a few weeks. Based on aforementioned two inputs, the CAD system will design the customized shoe last through a specified procedure. Visual C++ and OpenGL have been used for the system development, and the system consists of three main modules:

(1) automatic extraction of 18 important foot features from a laser scan of the customer's foot;
(2) a global grading together with a local deformation approach that can deform the base shoe last of the customer's chosen style to the customized shoe last based on the extracted foot features without altering the style of the base shoe last; and
(3) A color-coded map for the final evaluation of the fit/match between the reconstructed customized shoe last and the customer's foot.

Based on the laser scans of each participant's feet and the chosen shoe style, a pair of digital customized shoe lasts is generated through the developed CAD system and then delivered to a local shoe manufacturer. The pair of dress shoes manufactured was subjectively assessed for shoe comfort with a small sample size.

Shoe customization for individuals is achieved only on special cases, for example, elite sports or foot pathologies. The prices of customized shoes are not practical for the majority of individuals at the current stage. The additional costs from the shoe customization have to be controlled at or below 30%. This is not an easy task. Some limitations do exist in the CAD system proposed by Xiong *et al*. (2010) [25]. The operation of the CAD system needs the operator to have certain design experiences in setting appropriate tolerance, weighted parameters, which needs a good understanding of foot shape, pressure sensitivity, and tissue mechanical properties. The CAD system proposed by Xiong *et al*. (2010) [25] is based on the laser scan of the customer's feet standing on a flat platform; however, since the shoes are generally having heels for foot dynamics, the flattened foot may have different shape and dimensions when compared with the foot on the heel, especially on a high heel; thus, the aspect of how to model the foot shape on a certain heel height from the flattened foot in the process of customizing shoe last was omitted in the proposal by Xiong *et al*. (2010) [25]. The CAD system proposed, is sometimes time-consuming to perform good local deformation due to a few iterations.

Rodrigo, Goonetilleke, and Witana (2011) [17] classified 25 male and 25 female feet of students of Hong Kong University of Science and Technology based on match/ mismatch between foot and last based on top view into (a) good matching (b) mismatch in medial side (c) mismatch in lateral side and (d) mismatch in both medial and lateral sides.

National Sizing Standards for India (NSSI) (2013) is an initiative by National Institute of Design, Ahmedabad to develop a comprehensive and robust anthropometric data and standards for India. Many countries have used 3 D scanners and digital human modelling technology to carry out national sizing surveys and develop anthropometric databases based on 3 D body mapping. (http://www.nid.edu/Userfiles/ NSSI_Background.pdf). The scope of NSSI is whole body dimensions and not specific to the feet.

SATRA (Shoe and Allied Trade Research Association), Northamptonshire, UK provides Footwear Comfort Index (FCI) assessment which is a meaningful way of quantifying footwear comfort under controlled laboratory conditions such that a number can be assigned to define the overall level of footwear comfort. It comprises four elements: fit assessment, aesthetics and handle (softness, flexibility and texture), moisture disposal assessment and treadmill assessment. A scoring system assigns marks to over 60 individually assessed comfort factors. Fit assessment identifies problems in accommodating the target market population and specific fitting faults that might lead to discomfort. Aesthetics and handle uses a panel of assessors to systematically evaluate the feel and handle of materials and whole shoe construction. Thus, the customer's perception of comfort at point of sale - which influences the buying decision process - is evaluated. Moisture disposal properties of upper, lining and in-sock materials are considered with respect to wicking, absorption and permeability performance, and the overall ability of the footwear to manage sweat production. The key part of the Comfort Index is the assessment of physical comfort parameters on the foot during treadmill walking. Trained wearers respond to questions about different comfort factors of the shoe while walking on a treadmill at a set speed in the laboratory. Standard hose is worn and, before each test, a reference shoe is worn to standardise the procedure. Multi choice answers are shown to the wearers while walking so each one can be fully considered. The final Comfort Index is calculated by combining all the scores and applying weighting factors reflecting the relative importance of each parameter. An index below a certain number is rated as 'uncomfortable' with rising levels of comfort measured from 'moderately comfortable' to 'highly comfortable' at a high index number.

According to SATRA its Comfort Index provides a meaningful, quantified method of measuring comfort, which can differentiate between products as well as between materials or components in similar shoes. It quickly identifies the comfort strengths and weaknesses of new designs without the need for expensive and time-consuming wear trials, providing pointers to where product improvements can be made. (Gopalakrishna, 2014) [10]

Schmel (1999) [21], Optimer Hardsoft Ltd, Hungary as part the 'Final report on the foot measurement survey in India' submitted to United Nations Industrial Development Organization (UNIDO) surveyed samples of Indian feet using advanced computerized photometric method generating orthogonal projections of feet. Based on the foot survey the population was categorized into five coherent groups. Ball girth and width increments were recommended for the Indian population. Shoe last bottom patterns were constructed for all the five size groups. The parameters for the geometric modelling of the last were formulated. But assessment of long term comfort factors like pressure distribution on the sole of the foot, or weight and shock absorption properties were not part of the research. In practice anthropometric surveys are made at 90% confidence level (Schmel, 1999) [21].

Bata, Action, Liberty, Relaxo, J. D. Williams are retail brands

which offer a range of fittings for each size in India. NIKE seems to offer customized trainers and sneakers in India, in the price range of ₹.8,000 to 27,000 (US $ 120 - 406).
Thus the primary objective of the proposed research is to assess lasts of Indian men's work place casual footwear including aspects like match of toe shapes and redesign of lasts along with fit assessment and additional aspects closely related to long term comfort such as pressure distribution on the sole of the foot or weight and shock absorption properties which may be considered in order to improve model accuracy.

2. Method and procedures.

Reviewing previous studies on the foot, last and the shoe the following methodology has been planned for the proposed research.

2.1 Assessment of lasts

The effective last length, big and little toe depth, 70^0 joint width, joint and instep girths and other parameters of existing lasts of Indian men's work place casual footwear - Moccasin, boot, Derby, Brogue and Sneaker styles, would be measured using a special last assessment jig along with a pair of digital vernier calipers and flexible tape measure. The results would be compared against the appropriate Bureau of Indian Standards (BIS) guidelines.

2.2 Matching forefoot shapes

A series of 2 height, 7 length, 1 breadth and 1 girth measures of the right foot bearing full body weight of Indian office going men, would be recorded using a modified Mitutoyo digital caliper interfaced with a micro-processor or Easy foot scan hardware and software. The distance between the pternion and the distal extremity of the second digit expressed as a percentage of the Maximum Foot Length (MFL) would be calculated. In addition, the distance between the pternion and the distal extremity of the fifth digit relative to MFL would also be calculated. Data pertaining to around 200 north Indian males and 200 south Indian males would be collected. Based on these data the angle which the anterior margin of the foot makes with the long axis of the foot would be computed. Requirement of unique shoe lasts for different ethnic groups in the population for optimal shoe comfort would be ascertained. (Hawes *et al*, 1994) [12]

2.3 Construction of lasts

Based on the parameters proposed through the report submitted to UNIDO in the year 1999, lasts for mode sizes would be constructed for identified styles of Indian men's work place casual footwear.

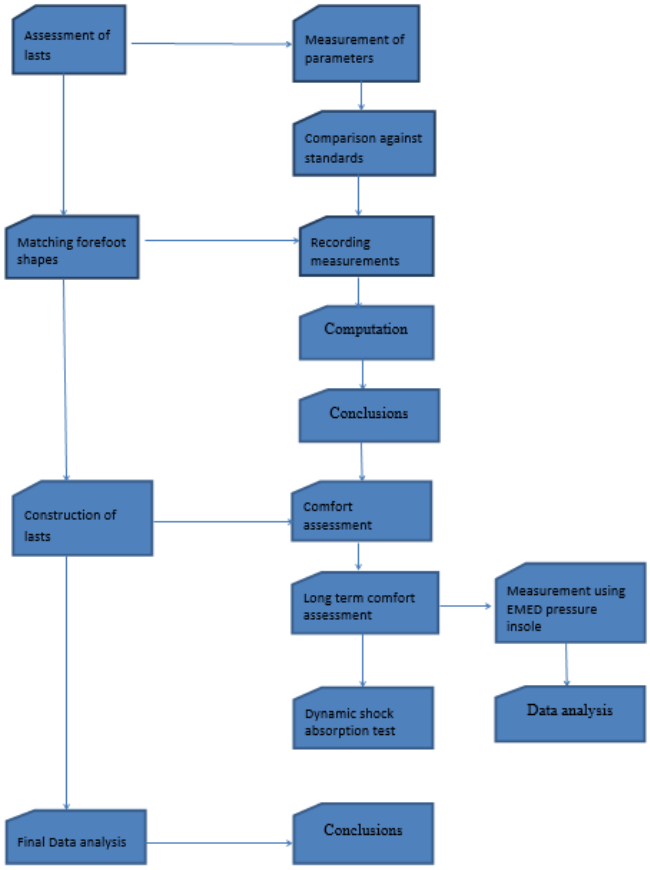
2.4 Comfort assessment

The SATRA FCI would be computed for the pairs of shoes constructed on the redesigned lasts as referred above.

2.5 Assessment of long term comfort

Long-term comfort of the constructed shoes, would be assessed using the EMED pressure measuring insole checking for even pressure distribution at the plantar surface of the foot while walking on treadmill at a speed of 5.8 to 7 km/hour. Peak pressure, pressure - time integral and maximal area and other variables would be used in data analysis. Also the SATRA dynamic shock absorption test would be carried out on the constructed shoes in order to improve model accuracy.

3. Work plan and implications



With the core objective of improving the satisfaction of men while wearing work place casual footwear the proposed research aims to assess lasts of Indian men's work place casual footwear including aspects like match of toe shapes and redesign of lasts along with fit assessment and additional aspects closely related to long term comfort such as pressure distribution on the sole of the foot or weight and shock absorption properties which may be considered in order to improve model accuracy.
Some of the anticipated problems likely to be found along the way are that the research project would require a budget/ funding. Matching the requirements of the proposed research and the priorities of funding agencies might be a herculean task and moreover the issue of availability of resources with regard to state of art laboratory facilities within the vicinity of National Capital Territory (NCT) where research is to be conducted also needs to be addressed.

4. Conclusions

Thus it is reiterated that the core objective of the proposal is to improve the satisfaction of Indian men while wearing work place casual footwear. The proposed research aims to assess lasts of Indian men's work place casual footwear including aspects like match of toe shapes and redesign of lasts along

with fit assessment and additional aspects closely related to long term comfort such as pressure distribution on the sole of the foot or weight and shock absorption properties which may be considered in order to improve model accuracy.

The broad outcomes of the research would be i) gap analysis as a result of assessment of lasts, ii) identification of groups which would require distinct redesigned lasts as a result of matching forefoot shapes and iii) results of long term comfort assessment of footwear constructed using the redesigned lasts might validate the research approach followed. An appropriate further decision needs to be taken at this stage, which would lead to further final conclusions. The findings would lead to a scientific approach towards design and manufacture of work place casual men's footwear in India, which would in turn contribute to better fit, comfort and consumer satisfaction, to sum up, implying commercially viable manufacturing for the enterprises.

5. References

1. Anand G, Alekya U. A study on consumer behaviour in the footwear industry. International Journal of Applied Services Marketing Perspectives, 4, 1768-1775. Retrieved from, 2015. http://pezzottaitejournals.net/pezzottaite/images/ISSUES/V4N3/IJASMPV4N313.pdf
2. Anand N. 'Size' does matter, Need for “Size India” - National Body Sizing Survey of Indian. Paper presented at Tech exchange, National Institute of Fashion Technology, New Delhi, 2011.
3. Bata Shoe Company (P) Limited. Introduction to basic designs, materials, components and constructions. In Footwear Design & Manufacture (pp. 10).
4. Chakrabarti D. Indian Anthropometric Dimensions. Ahmedabad: National Institute of Design, 1997.
5. Chien-Chung CR. An investigation into shoe last design in relation to foot measurement and shoe fitting for orthopaedic footwear. (Doctoral thesis). King's College School of Medicine and Dentistry, University of London, London, 1993.
6. Chen H, Nigg BM, Koning J de. Relationship between plantar pressure distribution under the foot and insole comfort. Clinical Biomechanics, 1994; 9:335-341. doi:0268-0033/94/060335-07
7. Cheskin MP, Sherkin KJ, Bates BT. The Complete Handbook of Athletic Footwear. New York: Fairchild Publications, 1987.
8. Ghosh A. Indian Anthropology, History of Anthropology in India. Retrieved from, 2008, http://nsdl.niscair.res.in/jspui/bitstream/123456789/519/1/PDF%204.11 HISTORY_OF_ANTHROPOLOGY_IN_INDIA01.pdf.
9. Goonetilleke RS. Designing for comfort: a footwear application. Paper presented at the Proceedings of Computer-Aided Ergonomics & Safety Conference (Plenary session), Maui, 2001.
10. Gopalakrishna G. Anthropometric characterization of Indian feet (Doctoral thesis). Anna University, Chennai, 2014.
11. Gordeyeva OV. 3D numerical modelling and manipulation of a shoe last (Doctoral thesis). De Montfort University, Leicester, in collaboration with Saint-Petersburg State University of Technology and Design, Russia, 1998.
12. Hawes MR, Sovak D, Miyashita M, Kang SJ, Yoshihuku Y, Tanaka S. Ethnic differences in the forefoot shape and the determination of shoe comfort. Ergonomics. 1994; 37(1), 187-96. doi:10.1080/00140139408963637
13. Helfet J, Lee G, David M. Disorders of the foot: Philadelphia: J. B. Lippincott Company, 1980.
14. Kumar SR. Shoe sizing systems. Fibre2fashion.com. Retrieved from http://images.fibre2fashion.com/ArticleResources/PdfFiles/47/4697.pdf
15. Miller JE, Nigg BM, Liu W, Stefanyshyn DJ, Mathew A. Influence of Foot, Leg and Shoe Characteristics on Subjective Comfort. Foot & Ankle International. 2000; 21(9):759-766.
16. Rao SV, Subashini K, Harish K. Management of HRD Requirements - A Case Study of Indian Footwear Industry. International Journal of Innovative Research in Science Engineering and Technology. 2014; 3(2):9824-9829. ISSN: 2319-8753. Retrieved from https://www.ijirset.com/upload/2014/february/55A_Management.pdf
17. Rodrigo AS, Goonetilleke RS, Witana CP. Model based foot shape classification using 2D foot outlines. Computer-Aided Design, 2011, 1-8. doi:10.1016/j.cad.2011.01.005
18. Rossi WA, Tennant R. Professional shoe fitting. New York: National Shoe Retailers Association, 1984.
19. Salminen TN. Footwear Sizes and Fittings. Chennai: Indian Institute of Leather Products. (page nos 2 – 4, 7-11,18-19), 1992.
20. Sarkar S. A Case Study of Footwear Industry in India. Retrieved from, 2011. http://www.ihdindia.org/Formal-and-Informal-Employment/Paper-4-A-Case-Study-of-Footwear-Industry-in-India.pdf.
21. Schmel F. Final report on the foot measurement survey in India (DG/IND/92/404). Retrieved from, 1999. https://leatherpanel.org/sites/default/files/publications-attachments/foot_measurement_survey_india_unido.pdf
22. Shoe Lasts and Foot Measurements. Chennai: Indian Institute of Leather Products, (page no. 76)
23. Telfer S, Woodburn J. The use of 3D surface scanning for the measurement and assessment of the human foot. Journal of Foot and Ankle Research. 2010; 3(19):1-9. doi:10.1186/1757-1146-3-19
24. Witana CP, Fenf J, Goonetilleke RS. Dimensional differences for evaluating the quality of footwear fit. Ergonomics. 2004; 47(12):1301-1317. doi:10.1080/00140130410001712645
25. Xiong S, Zhao J, Jiang Z, Dong M. A computer-aided design system for foot-feature-based shoe last customization. International Journal of Advanced Manufacturing Technology. 2010; 46:11-19. doi:10.1007/s00170-009-2087-7