2 Global Framework

This chapter is addressing aspects of how human living can be sustained on our planet earth. Challenges of sustainability are in overcoming the unequal distribution of wealth in different regions of the globe. Also the global population growth must be stopped by better standards of living without increasing resource consumption. A reference model of management and technology, innovative processes and products by modern research and education in different societal frames is presented. University education in student project teams from different continents developing and realizing innovative products and processes according to criteria of sustainability are identified as new means to accelerate creative imagination and implementation. The power of student engineering can help overcoming the barriers of management in established institutions often bound to traditional thinking habits and short term daily requirements. Approaches towards sustainability in engineering with focus on manufacturing are presented and illustrated by actual developments on vehicle recycling in China.

2.1 Wealth Distribution and Use Productivity

Günther Seliger, Berlin, Germany

Sustainability is directed to enhancing human living standards while improving the availability of natural resources and ecosystems for future generations. More than half of global value creation of today is achieved by less than one tenth of the global population. A sustainable political, economical and social stability can only be achieved if mankind is able to create jobs and living conditions of human dignity worldwide and not only in the technologically developed regions of East Asia, North America and Western Europe.

Human creative imagination, knowledge, experience, skills and initiative by entrepreneurial action coin our living conditions. Overcoming poverty requires a minimum of resources, abilities and qualification provided for everyone in the world to take initiative for value adding activities. On the other hand equal level of wealth for everyone with hardly any differences in people's living conditions takes away incentive for useful engagement. The course of accumulate income earned by a community population from the poorest to the richest member is described by the Lorenz curves. The equity factor relates individual welfare to overall equity (Figure 1).

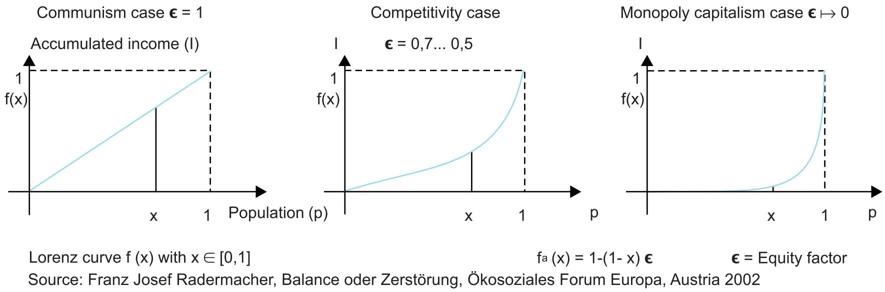

Fig. 1: Lorenz curve and equity factor: quantitative instrument for describing the inequality in a society [1]

Empirical statistical data show significant differences in equity factors within different countries and regions all over the globe (Figure 2). In reaching sustainability within the present globalisation process the crucial rule of achieving a higher level of equity worldwide is considered to be essential. More equity is a key concept discussed in the European Union to find consensus between regions of different levels of wealth. It is based on strictly limiting environmental burdens and co-funding development [2]. It is integrated in the idea of tenfold growth with tenfold eco-efficiency [3].

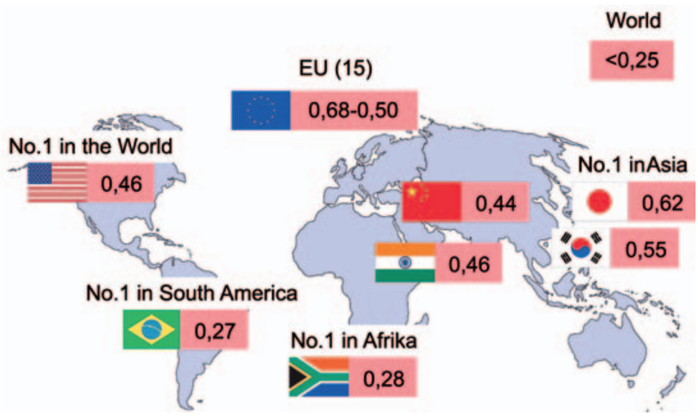

Fig. 2: Differences in equity factors [1]

The exponential growth of population on the globe must be stopped. Apart from unacceptable developments as war or disease a higher standard of living is the only means to reduce population increase. And if this shall happen without exceeding ecological limits the use productivity of resources must be raised (Figure 3).

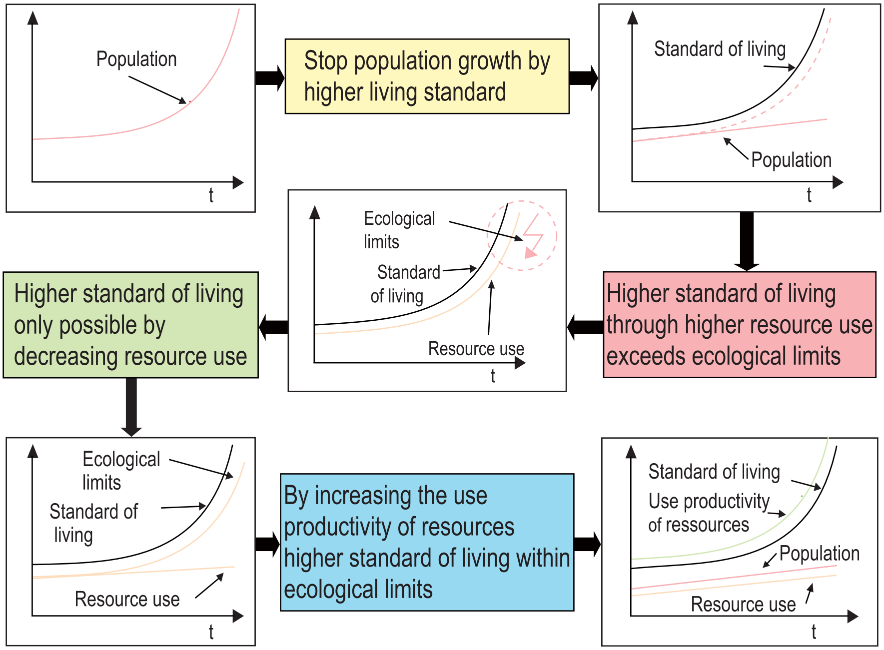

Fig. 3: Logical path for increasing use productivity of resources [1]

Engineering challenges derived from this requirement are design of processes and products with improved usefulness and less environmental harm. Technology interpreted as science systematically exploited for useful purposes offers huge potentials to contribute. Technology enables for processes transforming natural resources into products to meet human needs. The interaction between research and education imposes dynamics on how creative solutions are developed for relevant tasks. Due to new means of transport and communication knowledge and value creation is no longer limited to niches of wealth but more and more accessible by everyone from everywhere at anytime. These dynamics must be mastered by management considering chances for cooperation and risks of competition. Different societal frames with different value systems considering economical, ecological and sociopolitical issues in different regions of the globe have to be taken into account (Figure 4).

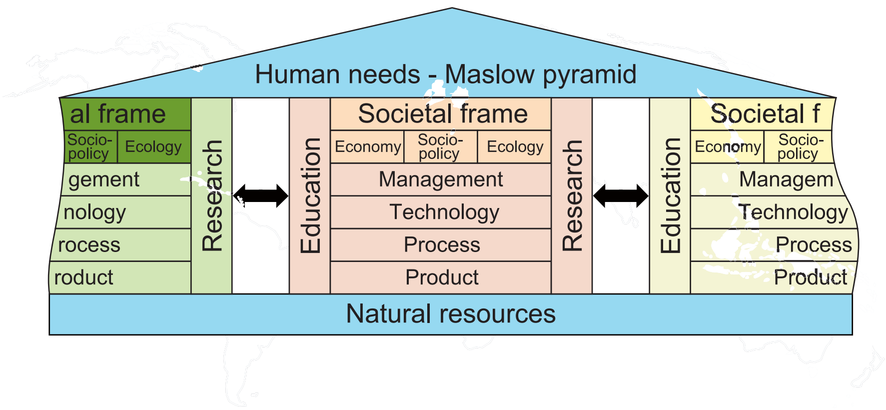

Fig. 4: Engineering challenges by sustainability [1]

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2.2 Education by Projects

Günther Seliger, Berlin, Germany

Management is challenged by innovation in sustainability. Innovation is defined as invention plus diffusion i.e. success on the market [1]. Both education and business are essential factors for the success of sustainability in a competitive market environment.

Today products and processes emerge by cooperation of generalists and experts in interdisciplinary teams. Project success depends considerably on the ability to communicate, present and document information. Another element of success is the ability to exploit creative potentials for useful applications (Figure 1). The balance between cooperation and competition among partners in development networks has to be diligently kept [2]. The global orientation of more and more big and small companies pushes international cooperation and calls for team members whose social as well as intercultural competencies are well developed.

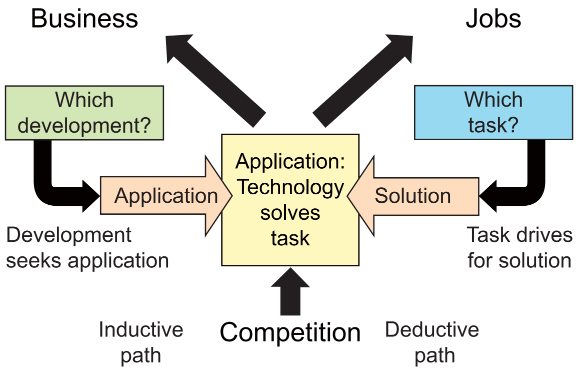

Fig. 1: Inductive and deductive innovation path [1]

Compared to ex-cathedra teaching work on projects in study courses enables students to achieve competencies and skills in addition to technical knowledge as well as to develop their personal attitudes.

In global experimental teaching courses [4, 5] jointly organized by universities from different continents the objective is on integrated transfer of methodical and social competencies utilizing expertise gained by means of case studies [3]. The few months long courses consist of internet-lectures organized by the teaching staff of the cooperating universities and a project-oriented work in continentally mixed student teams. During the project work, the students develop and prototype globally marketable technical products. The modular design of the products offers chances of adaptation to various global regions. Two meetings, early and late in the respective term, supplement the virtual meetings via internet communication by face to face communication of all participants.

Lectures are transmitted via modern multi-point and broadband video-conference systems, which allow location independent dialogues between students as well as between students and teaching staff. Moreover, international experts and industrial partners are able to communicate and supervise the students. The lectures refer to the topics marketing, conceptual design, product engineering, manufacturing and distribution.

The project work is based on the initiative of the students, who are assigned into multi-national teams of six students with two from each of the respective countries. The students choose the product to be developed by themselves based on a generic presetting. E.g. an "internet-ready product", a so-called "multiple-use-product" or a so called "learnstrument" has to be developed by the student teams. The idea of application in different markets of developed and emerging countries is considered. Also projects to be realized by student teams are given by industrial cooperation partners.

Student project teams are directed to developing technical products for the global market, which are marketable and prototypically realizable by their own skills. The project work covers almost all product development phases, from product idea generation and market analysis until standard assembly drawings and prototype manufacturing. Two design reviews combined with presentations take place during the project work in order to determine the team progress. In the two face to face meetings, at the beginning and the end of the course, the participants meet for the direct exchange of ideas and the implementation of their product concepts.

Experiences gained from education project course work indicate deficits concerning methodological and knowledge competencies in the cooperative development of product concepts, in the development of assessment criteria, in the documentation and communication of solutions and experiences, in the cooperative development of initiative, in the short and clear formulation using synchronous communication media. Deficits with respect to personal and social competencies have been identified in the cooperation before the first personal meeting, in the mutual respect for personal and cultural peculiarities, in handling of own expertise limits, in recognition of and intervention for solving technical and interpersonal problems i.e. said different from heard different from understood different from accepted different from own action. Deficits in competencies of decision-making and taking over responsibility could be discovered in the team decision process, in the sharing of work between the students under consideration of their different qualifications and preferences, in the balance of details and range of development, in the balance of work load and development quality. Organizational issues could be improved in the balance between management and control and moderation of teaching staff, in the coordination of lecture contents and knowledge necessary for project work, and in the resources availability due to regressive budgets of universities.

Continuous education becomes a crucial task of management in an industrial and societal environment which, due to technological developments and their accessibility by everyone from anywhere at anytime, is more and more coined by innovation. Success in running paths of sustainability is considerably dependent on how people can be convinced. Leadership in modern management requires abilities in teaching.

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2.3 Processes and Products

Günther Seliger, Berlin, Germany

Another challenge for management on their way to sustainability is how to apply chances of economic competitivity for ecological goals. Today, the remanufacturing of expensive, long living investment goods, e.g. machine tools, jet fans, military equipment or automobile engines, is state of the art. Remanufacturing has to be extended to a large number of consumer goods with short life cycles and relatively low values. Reuse is an alternative to material recycling to comply with recovery rates and quantities as well as special treatment requirements as prescribed by European legislation with the directive on Waste of Electrical and Electronic Equipment (WEEE) [1].

Some remanufacturing cases are widely known, e.g. the remanufacturing of single use cameras (Eastman Kodak and Fuji Film), toner cartridges (Xerox), photocopiers (Fuji Xerox, Australia, Netherlands and UK), commercial cleaning equipment (Electrolux) and brand name computers (IBM, France, Germany, USA; HP, Australia). Remanufacturers are OEMs themselves who have integrated new distribution models such as leasing or "pay per use" with remanufacturing strategies. Other remanufacturing practices, e.g. for washing machines (ENVIE, France), personal computers (ReUse network, Germany), accumulators (teldeon, Germany), cordless phones, car stereos, FM radios (Topp Companies, USA) and mobile phones (ReCellular, USA; Greener Solutions, UK) are less popular, due to the fact that OEMs are not involved. Products are not sold through regular retail channels established by OEMs [2].

Specific economical chances for remanufacturing can be identified in the selling use approach. Only the use of the product and not the product itself is the object of the trade. Product manufacturers or third party companies can act as use providers. The use provider offers the functionality of the product to the customer without passing the product out of his possession. He is responsible for the accessibility of the required utilization and the treatment of equipment over the entire lifetime. The use provider manages the costs of investment, transport, operation, maintenance and disposal. Consequently, the customers only pay for the use that they obtain by the product and not the product itself.

Selling use becomes more competitive, if the product providing the use can be adapted to multiple usage phases. Adaptation processes are necessary due to the change of technical features and user needs. Kinds of adaptation are maintenance, repair, remanufacturing, up- and downgrading, enlargement and reduction as well as, rearrangement and modernization. Adaptation often requires disassembly and reassembly. Additional processes are cleaning, treatment, component supply and removal, inspection, and sorting. A balanced strategy of preventive maintenance and repair preserves or increases the residual value of the products.

Fig. 1: Exemplary products enabled for sustainability [3]

Requirements on products for the selling use approach are modularity, integrability, customization, convertibility as well as diagnosability to support customer driven adaptability. The implementation of these properties increases the applicability and the availability of a product in multiple usage phases. In the selling use approach the use provider is responsible for the availability of the use at the right place and time in adequate quality. Therefore the use provider needs system-accompanying quality management, information and communication systems to guarantee product pursuit and product access. Leasing-, rent- and service-contracts regulate the responsibilities between customer and use provider. Selling use becomes competitive to selling products, once the idle capacity costs are higher than the extra costs to be paid for logistics, information and communication. Logistics include all necessary processes to provide the demanded use at the right place and time in adequate quality. Thus the effort for adaptation between two usage phases and the transport of the product are included as well. Modern information and communication give real time access for suppliers and customers on demand and availability of the specified function of use to be met by respectively adapted products. The Figure 1 depicts examples of products from Sfb 281 that were enabled for sustainability by means of process and product design and changes for new business models [3].

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2.4 Sustainable Recycling of End-of-Life Vehicle in China

Wang Chengtao, Chen Ming, Shanghai, China

By the end of year 2005, the volume of in-use vehicle was 35 million in China. It was estimated that the volume of End-of Life Vehicle (ELV) was 2.1 million and nearly 60 % of which were dismantled while others were still running. With the rapid development of automobile industry in China, it is estimated that, by the year 2010, the volume of in-use vehicle will be 55 million, and the end-of life vehicle will be 3.3 million; by the year 2020, the volumes will be 100 million and 8 million, respectively (Figure 1). At the year of 2001, Decree #307 about ELV disposal was issued by State Department of P. R. China. This is the highest law concerning about the disposal of ELV in China today. The ELV recycling industry is full of opportunities and challenges in China.

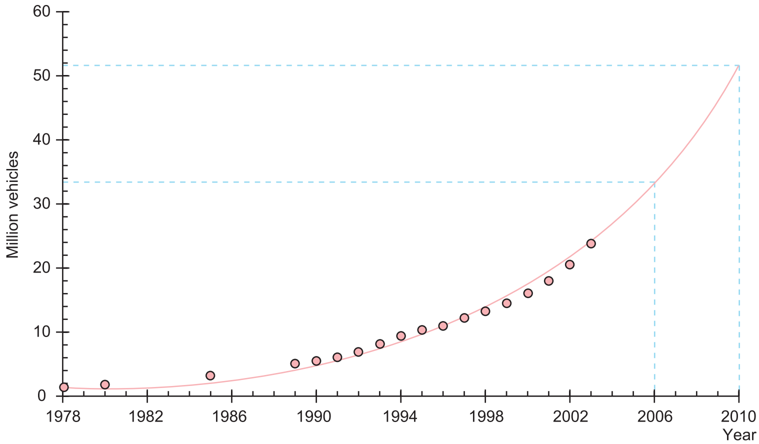

Fig. 1: Volume of in use vehicle in China

By the end of year 2005, Chinese government had implemented her 10th Five Year Plan (2001~2005) and set up 11th Five Year Plan (2006~2010) for the development of national economy. But along with the economic rapid growth, the issues of environmental protection and social inequity and inequality have also become increasingly tangible, and choice a sustainable way for China become stringent and urgent. On May of 2004, the National Development and Reform Commission (NDRC) issued the “Automobile Industry Development Policy”. This was a policy for economic development of Chinese automobile industry mainly aiming at “making the automobile industry a pillar industry in the national economy by the year 2010" and neglecting systematically addressing sustainability of automobile industry.

A new regulation about "The Motor Vehicle Product Recovery Technology Policy" was issued on February of 2006 by the NDRC, the Ministry of Science and Technology and the State Environmental Protection Administration (SEPA). According to the regulation, Chinese automobile manufacturers and importers will be responsible for collecting and recycling vehicles from 2010 or designating other authorized end-of life vehicle dismantlers to handle the business. The new regulation was designed to encourage domestic automobile producers to use more environmental benign materials. According to the regulation, Chinese automobile manufacturers are banned to using hazard and difficult-to-recycle materials in manufacturing. The new policy will surely raise the costs to automobile manufacturers and importers and poses a higher demand on technology innovation. But over the long term, it will help to increase the sustainability of the Chinese automobile industry.

2.4.1 Recycling Industry

Without professional equipments and management specifications, and, with small production scale, low dismantling efficient, low recycling rate, and environment pollution, it is that Chinese ELV dismantling industry is now facing. Almost all ELV dismantling plants have little idea about environmental protection and scientific, reasonable disposal technique. The waste fluids are not removed before dismantling process. Today, most of ELVs are dismantled manually in China with pneumatic and electric tools and oxyacetylene cutting because of the low cost of labour. The dismantling processing is random and unreasonable, for example, in order to dismantle a part for sale, the connection or other parts around it will be destroyed possibly. The secondary-parts are sold without any inspection and processing, partly because customs would like to see the condition of ELV from which the part is dismantled and determine its quality and price, and partly because the plants have no capability to processing and inspection. Shredding process is simplified to cut metal into big pieces for convenient transportation other than to grind into fist-like pieces.

Scopes of ELV

Depending on Chinese ELV standard (Issued by formal National Committee of Economy and Trade) the civil vehicles which is registered in China, should be discarded as ELV depending the following technical specifications:

- mini size commercial vehicles, including cross-country type, total mileage up to 300,000 km,
- light commercial vehicles, including cross-country type, total mileage up to 400,000 km,
- heavy, medium commercial vehicles, including cross country type, total mileage up to 400,000 km,
- passenger vehicles, including cross-country type, total mileage up to 500,000 km,
- others, total mileage up to 450,000 km,
- mini size commercial vehicles, including cross-country type, commercial vehicles with trailer and taxicab, total service period up to 8 years,
- light commercial vehicles and others, total service period up to 10 years;
- the vehicles whose total service period over the fixed number of year as mentioned above, except the taxicab with less than 19 passengers, light and mini size commercial vehicle including cross-country type, could prolong their service period up to half of the fixed number of year as mentioned above on the condition of inspection up to grade by vehicle administration according to national vehicle exhausts standard (GB7258—2004).

Characteristics of ELV in China

The characteristics of ELV in China are mentioned as following:

- There is difference in condition of ELV of eastern, central and western regions of China. The ELV of eastern China is in better condition than that of western China because of the advancing in economy of eastern China and consequently the higher requirement of vehicle users;
- There is a big number of end of life commercial vehicles in China, and the proportion of personal car is small at present. It is a tendency of increasing in proportion of end-of-life personal car from now on;
- There is a tendency of increasing in obsolete imported vehicles because of the big imports of vehicle in early 1990s. Passenger cars accounted for the biggest proportion in imported vehicles. For instance, in 2000, the proportion of passenger cars was 51 % (21,614 vehicles) and the proportion of cross-country vehicles was 20 % (8,668 vehicles). The proportion

of imported trucks and buses added up to less than 30 %. The recycling of end of life imported vehicles is mainly in metal materials because the utilities of vehicle are limited to business and official, and therefore, there is no market for reused parts in this stratum. On the other hand, some domestic auto parts remanufacturing plants imported cores from US and Japan, and sale abroad after remanufactured. So the gaps between the recycling of end of life imported vehicle and the outbound remanufacturing of auto parts and assemblies should be considered.

Patterns of ELV Recycling Industry in China

There are four scopes of industry in ELV recycling and remanufacturing in China:

- reverse logistics and dismantling of ELV,
- remanufacturing of typical parts and assemblies,
- recycling of materials;
- waste disposal and environmental protection in ELV recycling industry.

There are six kinds of ways to reuse and recycle materials after ELV dismantling in China:

- *Parts reuse:* Some reusable parts come into vehicle after-sales market or return to vehicle manufacturer for assembling;
- *Reuse after remanufacture:* The remanufactured parts mainly come into vehicle after-sales market for maintenance;
- Reuse in debasement: Some parts are not qualified in vehicles but could be applied in other products or services, such as the obsolete tires in bank of river;
- *Material recycle:* Most of recyclable materials, such as metals and plastics, are reclaimed as recycled materials;
- *Energy recovery:* Some materials, such as tires, lubricating oils, are recycled by the way of incineration, and the recovered energy could be used for recycling industry itself or other applications;
- *Landfill:* The shredder residues have to be land filled in junk yards.

Vehicles Recycling and Reverse Logistic Infrastructure in China

There is difference in economic development of eastern, central and western regions of China. It comes into being the characteristic Chinese economic development pattern. The regional difference in economic requirements and consumptions leads to the obvious difference in vehicle consumptions. The new vehicles begin their life cycle in eastern and end of life in western. The development and layout of Chinese vehicle recycling industry should consider this social fact. Therefore, we propose a model of vehicles recycling and reverse logistic infrastructure in China (Figure 2).

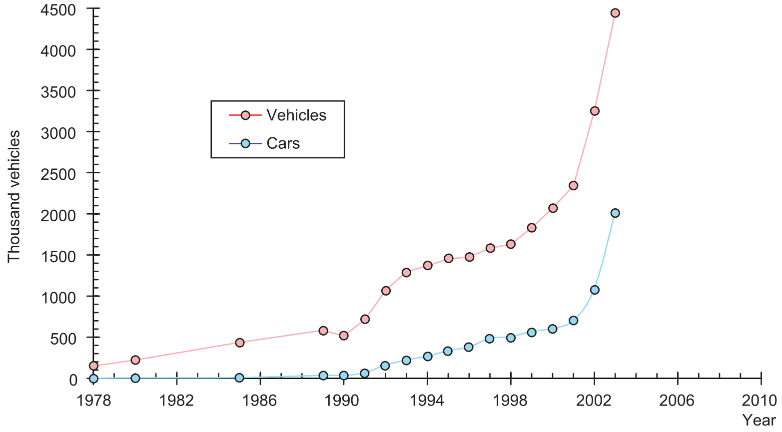

Fig. 2: Production of Vehicles in China

In central and western regions of China, a lot of ELV dismantlers should be established and accept obsolete vehicles. After being dismantled, the auto bodies, tires, plastics and used oils should be treated locally. For instance, bodies are recycled as scrap steel; tires and plastics are recycled as crushed powder. The effective and low-cost process and equipment should be developed and applied in dismantlers of this regions.

The repairable parts and assemblies which are collected in dismantlers or service stations should be sent to remanufacture industry after gathering of a certain amount. The remanufacturing enterprises could be specialized or comprehensive, and could be independent or belonged to vehicle manufacturers. The remanufacturing parts came into spare parts market. The failure parts in service stations are replaced and treated as the same as those in dismantlers.

Dismantlers collect direct reusable parts and send to Original Equipment Manufacturers (OEM) or vehicle manufacturers respectively via logistics between service stations and vehicle manufacturers. The automotive suppliers should establish their specialized workshops or departments for dealing with those parts which could be reassembled after strictly quality checking and testing.

2.4.2 Remanufacturing Activities

A Shanghai-based end-of-life vehicle recycling pilot demonstration system, which could disassemble obsolete commercial vehicles for spare parts, and recycle the rubber, plastic and metal material out of which vehicles are made. The project is the first ELV recycling system in Shanghai after the promulgation of Decree #307, and may lead to the establishment of other similar systems in regions at prefecture level and above with qualification cognizance all over China.

The dismantling plant, which is the heart of the system, includes equipment for disassembling big size commercial vehicles (vehicle mass >5 ton), including pre-treatment for the safe, environment-friendly removal of liquids, and also capability for separating the different materials for recycling. Combined, the rubber, plastic, metal and reused parts and assemblies are weighed more than 12,500 ton/a, and annual profit is about RMB ¥ 2,280,000 (i.e. US$ 274,368). Preliminary indications are that the project could be profitable and sustainable in China. Figure 3 shows the layout of pilot demonstration ELV dismantling plant.

However, the most significant advantages are the low cost of labour, which might allow the low cost facility to process vehicles, as well as the large potential source of vehicles and the significant numbers of consumers of reusable and remanufactured parts.

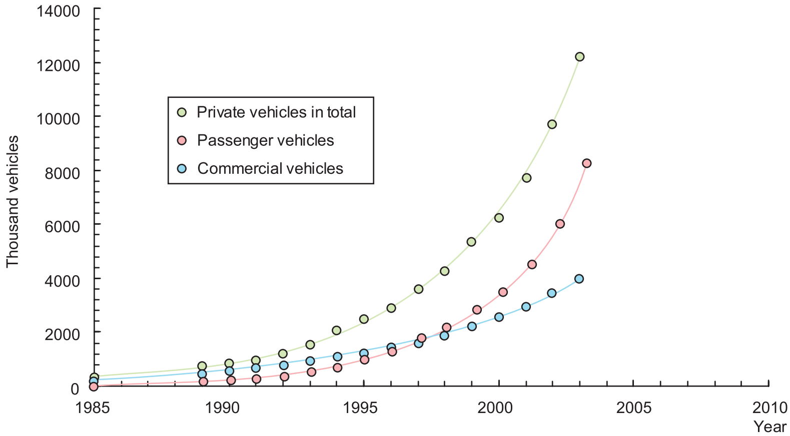

Fig. 3: Volume of private vehicles in China

The dismantling plant is housed in a facility of at least 20,000 m^2, much of which is used for storage. However, there will be space to expand the facility to incorporate some of the material specific recycling and parts remanufacturing modules. For example, today, an auto engine parts remanufacturing workshop is on establishing. It will result in an expansion of the secondary-parts market in China, which would compete with new, OEM-compliant and -guaranteed parts. And, the remanufacturing and sales of parts are likely to be important parts of the pilot system's success.

Shanghai Jiao Tong University, with financial support from the Science and Technology Commit of Shanghai Municipal Government, is collaborating with joint venture entrepreneurs who manage the facility. The university is responsible for environmental issues, and for the co-ordination of the factory layout and remanufacturing issues.

In fact, the level of development on ELV recycling industry in China is still low, and Shanghai should be responsible for establishing an pilot demonstration engineering system on ELV reduce, reuse and recycle, prompting the sustainable and orderly development of national-wide ELV recycling. Therefore, the goal of the pilot demonstration system is to establish an ELV recycling engineering system which matches to the reputation of international metropolis of Shanghai, and thoroughly remould the ELV recycling industry from extensive to intensive and environmentally benign industry and thereby promoting the sustainable utilization of natural resource and advancing the orderly development of ELV recycling. Depending on the policies and laws about ELV disposal including the Decree #307 issued by State Department in 2001, Shanghai municipal government consolidated the ELV recycling industry by means of administrative command, and the former 14 official designated ELV recycling enterprises were cut and merged to present 4 enterprises.

Technical Innovation

To achieving the goal mentioned above, the ELV pilot system project is focused on the following key finds and technical innovations:

- *A scientific and practical administration system for ELV recycling in Shanghai is established.* An municipal-wide information platform for ELV recycling administration is constructed. It is made up of "Shanghai ELV Administration System" and "Operation Flow Management System Software for ELV Dismantler", and it carries out the multi-layered and multi-noded functional management of monitoring, coordinating and administration among municipal governmental departments, ELV dismantler managing departments and ELV dismantling workshops. The recommendations for ELV related local policy and administrative regulation are proposed as well.

- *A pilot demonstration ELV dismantling plant is established.* The project focused on following 6 tasks:
  - demonstration of visual image and corporation image (VI/CI),
  - demonstration of recycling process of ELV,
  - demonstration of facilities for dismantling,
  - demonstration of clean production of ELV dismantling,
  - demonstration of logistic and storage of ELV dismantler,
  - demonstration of reused parts and assemblies examination and remanufacturing.

The technique innovations of the project focused on following:

Based on the abundance of Chinese labour and the increasingly strict requirement of environmental protection, a systematic green production specification and technological process is developed for ELV dismantling plant, and it results the improving rate of ELV recycling. The proportion of reused parts is raised from 22.5 % up to present 31.7 % in weight and the landfill is reduced from 10 % to 4 %.

Based on the requirement of residual fatigue life prediction for reused parts, an evaluation measurement and patented apparatus are developed for residual fatigue life prediction of used auto crank, which is taken as experimental objective. The dangerous sections of used auto crank are evaluated for cracks and stress concentration via eddy current testing and metal magnetic memory inspecting respectively, and therefore, it comprehensively evaluated whether the used parts are worthy of being remanufactured.

- *A primary pilot demonstration network of reused auto parts is established* (Figure 4). It includes some downstream designated reuse and remanufacture industrial enterprises which is specialized in reclaiming and disposal of used auto parts. And the aspects of corporation image, qualification, technological process, equipments and environmental protection are of comparative sense of demonstration.

Effects in Practise

Economic feasibility – The general investment of Shanghai pilot demonstration system of ELV recycling is about RMB ¥ 10 million (i.e. US$ 1.2 million), and its annual profit and revenue duty in total is about RMB ¥ 4,100,000 (i.e. US$ 496,368). The rate of return on investment is 22.8 %.

Achievement in recycling – The proportion of reused parts is raised from 22.5 % up to present 31.7 % in weight and the landfill is reduced from 10 % to 4 %.

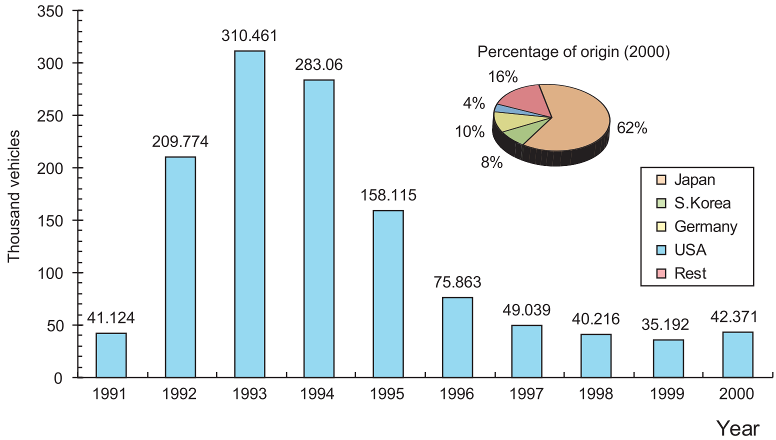

Fig. 4: Imported vehicles in China

Engine Remanufacture

There are, and only, two engine remanufacturing factories in China. One is for *Volkswagen* engine remanufacturing in *Shanghai*, (*Shanghai Volkswagen* Allied Developing Co., LTD.) and the other is for *Styr* engine remanufacturing in *Jinan*, *Shandong* Province (*Jinan Fuqiang* Power Co., LTD.), which is a Sino-Britain joint venture enterprise and a member of Production Engine Remanufacturers Association (PERA, www.pera.org).

Because of the potential market in remanufacturing, plenty of experienced technicians and lower cost of labour, nowadays, China is becoming a hot area for remanufacturing operations and investments. For example, an US based engine remanufacturing equipment provider, Sunnen Mechanical Co., LTD., has landed in China for two years. Sunnen says it will provide not only the remanufacture equipments but also the technologies and services for Chinese engine remanufacture industry. Caterpillar (Caterpillar China Investment Co., LTD.) has also established its Asia & Pacific Remanufacturing Services Office in Shanghai, today. However the engine remanufacturing is still restricted and controlled in China, because of worrying about the illegal piecing together the vehicles as mentioned before.

Dynamotor, Actuating Motor Remanufacture and Others

There are some factories in remanufacturing dynamotors, actuating motors, constant velocity joint and power steering. Such remanufacturing factories are small and flexible, and, some of them are automotive parts OEM supplier. The quality of their remanufacturing parts is perfect, and they are provided with the same quality guarantee as new OEM automotive parts. The price of those secondary-parts are 1/3~1/2 of new OEM one. It seems a brighter future of secondary-parts remanufacturing in China.

Surface Engineering in Engine Remanufacturing Industry

The normal procedure of remanufacture, for example, main bearing houses, is to enlarge the holes and replace thick bearings. It is difficult for user to repair here further, because the thick bearing is hard to get in market. With surface engineering, it is easy to reach the dimension and surface condition as same as original parts required, besides lower cost, The surface engineering technique is applied in practice for *Styr* engine remanufacturing (Figure 5). The practiced surface engineering techniques include:

- high-speed electric arc spray technique for repairing main bearing houses in engine body,
- electric brush plating technique for repairing cam journals, crank journals, rod and other bearing houses,
- micro pulse cold weld technique for repairing flaw in engine body.

A State National Key Lab for Remanufacture was established in Beijing, year 2003, aiming at fundamental research and practical applications of surface engineering technology for rapidly developing of remanufacturing industry in China. The applications of newly developed nano-scale surface engineering, such as nano-materials brush electroplating, nano-materials thermal spraying and nano-materials self-repairing antifriction additive technology, show the superiority in remanufacturing industry to the traditional way.

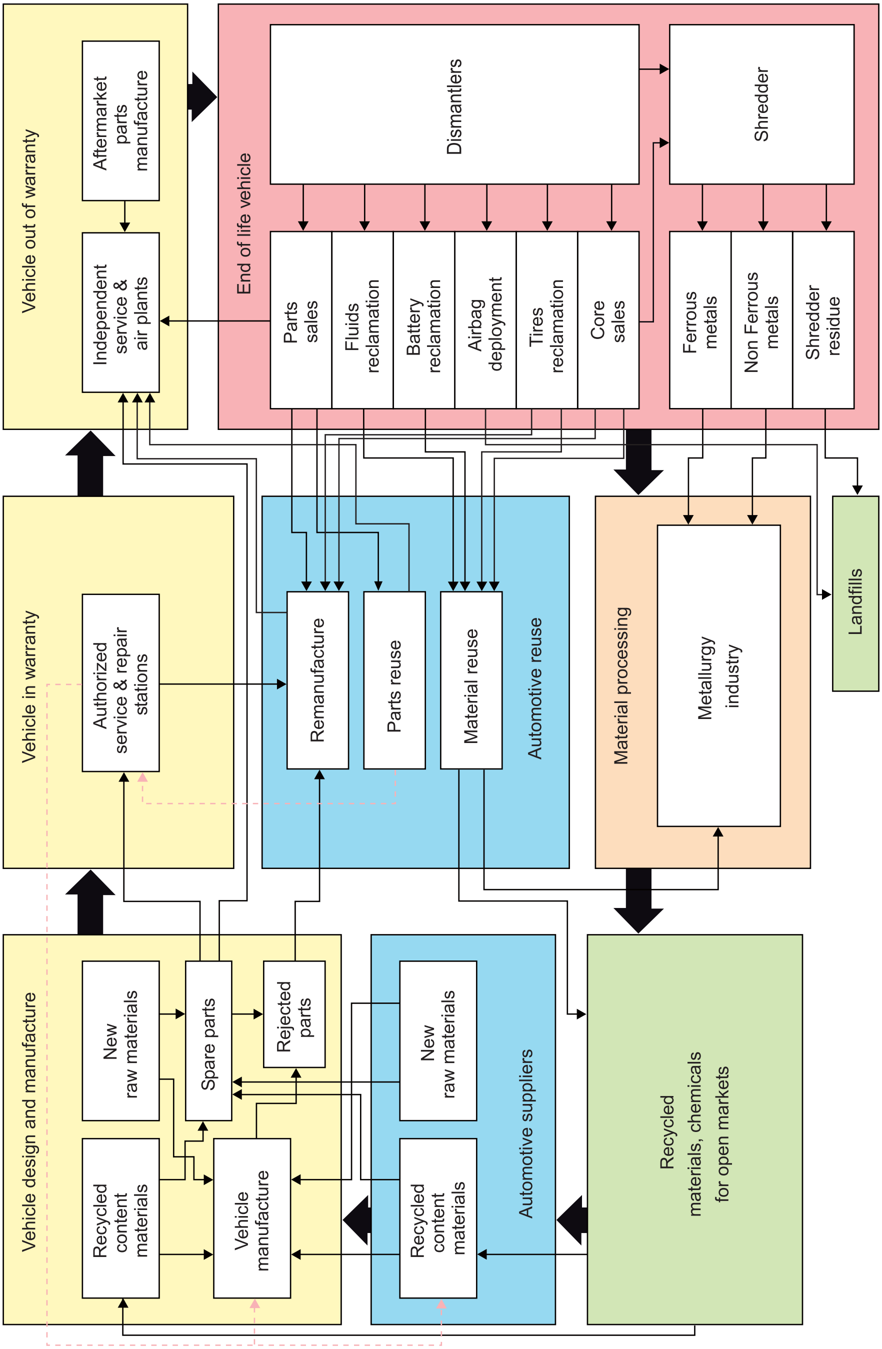

Fig. 5: Vehicles recycling & reverse logistic infrastructure in China

Residual Life Estimating for Core

The residual life of parts is important for remanufacturing. A systematic estimating method is established for residual life of core before remanufacturing. Base on the measuring of flaw and broken characteristics of parts material, the newly developing method is attempting to estimate the residual fatigue life of parts. It integrates the inspection of macro cracks with eddy current testing, and estimation of forepart of damage and weakening of anti fatigue capacity with the metal magnetic memory inspecting technique. The method is being implemented and validated at the Shanghai Jiao Tong University.

2.4.3 Challenges

The general objectives till year 2010 are identified as "Remould Chinese ELV recycling industry thoroughly from extensive to intensive and environmentally benign industry with technical innovation, promote the sustainable utilization of natural resource and advance the orderly development of ELV recycling":

- implement the information exchange platform for ELV disposal monitoring and administration within local administrative district;
- establish and perfect systematic technological specifications for "sustainable ELV recycling";
- research and develop technology, process, facilities and equipmentsfor sustainable ELV recycling, which are adapted to the situation of China and accorded with the practicalities of Chinese ELV industry, and the following technological issues should be focused on:
  - the clean dismantling process for ELV,
  - the technology and specialized facilities on identification, sorting and pre-treatment of nonferrous metals and plastics materials for ELV,
  - the thermal/cold cleaning technology for core,
  - the measuring and assessing technology of residual service life for core, and
  - the advanced level of proportion of reused parts and the rate of ELV recycling.

Outline for the State-of-the-Art

- *The investigation on the information system for monitoring, management and administration of whole life cycle of vehicles (design, manufacture, sale, aftersales service, dismantling, scraping, reuse and recycle) and its technique specification system.* Subjected to the Decree #307, the information system for ELV monitoring and administration and the systematic local administrative specifications should be developed within local administrative district. The auto manufacturers should be involved in collaborative researches on systematic specifications, legislations and sustainable ELV recycling activities. It is lacking of extended manufacturers' responsibility for ELV disposal till now in China.
- *The investigation on the state-of-the-art in the clean dismantling process for ELV.* New technologies, such as water jet cutting, should be applied in practice of dismantling in order to control and reduce volume of gas, liquid and solid waste in process.
- *The investigation on the state-of-the-art in the identification, sorting and pre-treatment of materials for ELV.* The technology and facilities specialized on identification, sorting and pre-treatment of nonferrous metals and plastics materials for ELV should be developed in order to upgrade the efficiency and quality of material recycling. A portable infrared based plastics identification technology and apparatus could be applied in non metal recycling of ELV. The recycling of nonferrous metals such as aluminium, magnesium, copperalloys would be implemented depending on casting alloy or forging alloy. The identification and sorting of nonferrous parts would be mainly manual operation and it is adaptable to the situation of China. The thermal/cold cleaning technology and equipment could be applied in cleaning of core.
- *The investigation on the state-of-the-art in the measuring and assessing of residual service life for ELV core*. The model, criteria and facilities for residue service life measuring and assessing should be developed based on non-destructive testing techniques such as, metal magnetic memory and infrared thermal imaging, and the mechanism of damaging and degradation of reused parts on complexservicing circumstance as well.
- *The investigation on the state-of-the-art in the surface engineering for ELV core*.
- *The investigation on the "3E – Environment Energy Economy" assessment for sustainable ELV recycling industry in China*. Environmental management of the total materials cycle must evaluate the effect of changes in processing or material substitutions, where materials use, reuse,

component remanufacture, and materials recycling can be considered and the overall costs and impacts assessed.
- *The approaches on education and dissemination for sustainable ELV recycling in China.*

Roadmap

The approaches for development of ELV recycling industry in China should be considering followings:
- establish the information system of monitoring, management and administration for whole life cycle of vehicles and its technological specification system;
- establish the big scaled “Recycling Centre for ELV” and its well organized reverse logistics. The centres could be either the state owned and designated ELV recycling corporations or the steel industry invested and steel scrap oriented ELV recycling enterprise. The centres should be responsible for the research and development collaboration of ELV recycling among government, industry and university;
- establish the “Remanufacture Centre for auto parts” which relies on the technologies and specifications of auto manufacturer and supplier, and it should be collaborating with insurance agent for the potential auto repairing market;
- establish the broad international communication and cooperation with, for example, US, EU and Japan on technique, management experience and industrialization of ELV recycling.

The following points should be considered on approaches for development of sustainable ELV recycling in China:
- R&D for easy-to-recycle materials and parts;
- diminishing the category of materials used in vehicle manufacture;
- design for dismantling and design for recycling;
- extending the category of reused and remanufactured parts, and raising its ratio to recycling in materials;
- reducing and disposing shred residues;
- R&D for clean energy recovery;
- Life Cycle Assessment for ELV recycling techniques.

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