

# Life-Cycle Eco-Services for Sustainability

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**Abstract.** The paper addresses the sustainable growth, or even better: ‘sustainability’ as a challenge for tomorrow, to assure progress continuation. From engineering viewpoints, the bet has to be accepted, and the ‘service economy’ provides valuable hints, affixing chances, with innovative worth. Pertinent details are specified, with links to the net concern deployments. The paper gives a survey and some genuine ideas to understand some crucial problems of mankind, which were out of scope for several hundreds of years and became important – at least some people started to understand and explain – only in the second part of the previous century, namely problems of ecology, of environment, of expectable energy and material shortages, including drinking water, which all together led to the acceptance of sustainable growth and then of sustainability. Sustainability may mean our survival from technical and social point of view as well. The importance and management of services – besides the production – will be discussed in details. Personal and company level issues will be analysed, as well as international and European Union level problems and solution efforts. Life-cycle management of traditional and extended (virtual) organizations, and the tangible and intangible properties and views of all types of objects are discussed, too

**Key words:** current industrialism, progress, service engineering, virtual settings, integration choices, prospects.

## INTRODUCTION

The growth sustainability is impending threat of the ecology globalisation, showing the over-depletion and over-pollution trends of the current industrialism. The analyses suggested that the civilisation continuance is option or bet, to be grounded on radical changes, i.e., on the ‘cognitive revolution’, bringing the intangibles to critical position for the prosperity, rooted in the ‘anthropic principle’, which states that the man intervention allows creating artificial settings, granting ‘value added’ out of the original wilderness [1–10]. The ‘civilisation’ is rooted in series of intentional alterations of the surrounds, promoting artificial shifts to men’s steered improvements. These particularities are instigated by the relational ‘intelligence’ singularity, entailing modifications conceived in the abstract mind worlds and (actually) verified useful, once transferred into operative plans. The mind world is origin of ‘knowledge’: its effectiveness exists if coding, sharing and storing abilities are enabled, ending in determined ‘culture’ and ‘ethics’ artefacts [11–20]. The ‘civilisation’ alterations track combined issues, discriminating:

- the interpersonal relationships, inventing effective ‘collective orders’;
- the natural resource exploitation, discerning ‘technology revolutions’.

The alterations are thought improvements, since the life-quality increases, compared to wild-life conditions. The development is believed entailing man inventions, which create value added by purposeful alterations, named ‘human’, ‘material’, ‘financial’ and ‘technical’ capitals. The ecology has recently obliged to look at the utilisation of earth resources, debased in wastes, and making unsafe the industrialism. The investigation reviews some basic topics, to suggest changeovers, typically, addressing the ‘service economy’, with two fold purposes: to provide monitoring aids and to explore recovery/remediation chances. The ‘human capital’ plays constituent and instrument roles, since the archaic social breakthroughs enabling ‘collective orders’, by group selection, or, lately, by nation-state differential effectiveness, until, desirably, by knowledge society advance. The ‘natural capital’ is indispensable supply of value-added transformations and is critical datum, with the industrialism

over-consumption and over-pollution. The ‘natural’/‘technical’ capitals are artificial entries, used to depict the intangible construal of the mind worlds, supplying intangible frames, to make manifest the administrative, economic, political and social advances of the timely qualified ‘collective orders’.

The ‘civilisation’ peculiarities have intangible trait, but need tangible provisions. The ‘cognitive revolution’ moves from knowledge society advance, using robot age innovation, instigating ‘to de-materialise’ and ‘to re-materialise’ processes with source restoring and biosphere reclamation purposes, rooted in artificial life-and-intelligence chances. This is bet, whose feasibility runs not only into technology confronts, but as well into socio-political defies.

The ‘anthropic principle’ says that the exam shall be tackled, as this is man’s task or mission. It, further, tells how our knowledge imposes rules, which select, out of many possible environments, those laws, leading to the ‘life’ and ‘intelligence’. The ‘civilisation’ becomes tautological upshot, having the holistic reading of the quantum dynamics relating the general relativity. The quizzical hypothesis deserves notice, even if lots of doubts are present in the amazing cosmologic backdrop. Then, the relational ‘intelligence’ plays the role of constituent enabler, along with evolution paths, towards the hoped progress. If the sustainable growth is the new threat, the ‘cognitive revolution’ is, with a bit of luck, winning defy and, perhaps, much more!

### PROGRESS AND INDUSTRIALISM

The industrial economy is based on the effectiveness in transforming raw materials into useful goods for the satisfaction of wide amounts of customers; the amazing productivity has a drawback, in the change of natural resources into waste and pollution, without allowing natural recovering (even while conceivable, out of the relentless entropy decay of the entire physical world). In science and technology domains, the urgency of the ‘sustainable’ growth is emerging as trans-disciplinary demand, to assure less eco-penalising wealth creation, so to manage the over-consumption and over-pollution, in view of the over-population increase.

In that context, the ‘service science’ plays fundamental role, with, basically, the twin duty of qualifying and expanding the value added in intangibles, and of supporting and provisioning the knowledge for the tangibles recovery. Truly, the ‘servicing infrastructure’, through world-wide-web and net-concerns, is winning chance to enable the

eco-consistent behaviours according to the two paradigms [21–30]:

- to de-materialise, by trading ‘functions’ that replace the good ownership, still enjoying the annexed utility, reliably supplied at the point-of-service;
- to re-materialise, by contributing the ‘recovery’ instruments to the reverse logistics and to the bio-mimicry resources reinstatement processes.

The ‘service infrastructures’ are essential fall-outs of the knowledge entrepreneurship, when the value chain is especially turned to the information and communication technologies and to the connected supporting know-how, while the material supply chain is reduced to become the auxiliary complement. The opportunity exists, with noteworthy achievements also in the past, in the delivering of ‘mobility’ or ‘computation’, to replace the car-fleet or the mainframes ownership. With the ‘service science’ for the growth sustainability, the idea is to aim at the structured approach, to identifying, analysing and solving the business-related issues of clients’ needs satisfaction, according to the quoted to de-materialise and to re-materialise paradigms, with pervasive resort to ambient intelligence, namely, to ubiquitous communication and computing aids [31–40].

### INTANGIBLES DRIVEN SUPPLY CHAIN

Within the service sector, several academic disciplines exist that shall be simultaneously considered in order to achieve optimal results, e.g., operations management, marketing policies, human resource programming, information technology, design innovation, and so on. The sustainable growth, today, really represents the enabling spur, through the transparent ruling and acknowledgement of the eco-impact, out-coming from the tangibles supply chains. Basically, all who are interested in sustainable growth require deep understanding of the Service Science, and advanced exploration on how the servicing infrastructures would modify the earlier manufacture organisations, to put in the market the enhanced ‘products-services’(say: ‘extended artefacts’), consistent with more eco-conservative behaviours. The idea of the prospected changeovers is to look after new operation infrastructures, shaped into ‘extended enterprises’ with suitably configured service orientation, either on ‘virtual organisations’, with duty-driven ephemeral architectures, exploit-

ing the facilities/functions trading, through net-concerns and special purpose brokerage aids [41–50].

### THE PRODUCT-SERVICE ORGANISATION

The attention to service engineering comes out almost obviously as technology-driven opportunity, when one perceives that ICT is enabling instrument, to establish the information value chains for the product lifecycle management. Indeed, the environment protection lumps producers (which profit of the natural resources, by transforming them into products) and users (which enjoy of the deliveries, to satisfy individual needs), into the unified consumers side (which take direct benefits, and scatter the eco-impacts over guiltless people and future generations), and establishes sets of behavioural constraints, progressively expanding the construction files to include, since the design and development stage of a new item to be put in the market, to include the lifecycle accountability, Fig. 1, of the whole supply chain.

- the on-duty operation specification, through fitting product lifecycle manager, PLM;  
 - the conformance assessment setting, via suitable service engineering, SE, provision;  
 - the end-of-life recovery (reuse, recycle) duties, by the reverse logistics, RL liability.

**Fig. 1.** Database of the Producer's extended Responsibility

The entrepreneurial lay-out shall evolve, extending the conventional bent onwards manufacture business, to encompass wider 'externalities', say, the PLM, the SE and the RL frames, which, one after the other, include on-duty product-data responsiveness, operation conformance assessment commitment and end-of-life call-back responsibility, as standard business requirements. The agenda evolves as for knowledge contents and as for task allocation, Fig. 2, progressive covering the obligatory eco-targets.

The resulting entrepreneurial lay-out is, typically, referred as 'extended enterprise', merging, into a shared infrastructure, skills, know-how, facilities and resources, to enable co-design, co-manufacture, co-market, co-maintain, co-servicing, co-recovery, etc. efforts, to offer 'products-services' at purchaser's benefit and environment safety.

- from (mainly bilateral) supplier-to-customer responsiveness, with small concern on eco-consistency; at this level, appropriate PLM aids are purposely implemented, with stress on the 'product' operation life;
- through (jointly liable) consumers' commitment, to reach eco-conservativeness by voluntary agreements; at this level, advanced SE tools aim at competitiveness, focussing, e.g., on the maintenance 'service' duties;
- to (sole) manufacturers responsibility, to comply mandatory targets under environmental acts; eco-design is best-practice for the supply chains, when free take-back and enforced recovery are compulsory commissions.

**Fig. 2.** Towards producer's extended responsibility databases

The 'product-service' or 'extended artefact' is any provision joining the manufactured commodities and the enabling utilities (the artefact is any object made by man with skill, especially with a view of subsequent use). The delivery of 'extended artefacts' is the consistent business of 'extended enterprises', in which the return on investment is achieved through 'externalities', say, through PLM-, SE- and the RL-driven duties. Today, the competitiveness turned on 'externalities' starts to be said as 'advanced' option, as the leading consumers (manufacturers) responsibility towards third people is, only, at a very early stage, and very few (far sighting) companies possess well-structured PLM and proper lifecycle assessment checks, forecast the offer, through voluntary agreements; of SE ambient intelligence for on-duty maintenance, and develop proprietary recovery policies for the already enacted mandatory targets in the RL frames. A cultural gap, possibly, exists, because the attention on 'external' functions and the provision of 'targeted' services are, by their very nature, trans-disciplinary efforts, and do not belong to the conventional domains of the manufacture processes.

### THE EXTENDED / VIRTUAL SETTINGS

It is time for the service science to be structured as self-consistent sphere, because of its relevant economical fallouts as for the emerging manufacturing organisations and unified technical background of the information layouts, affecting the knowledge entrepreneurship. The anomaly of 'extended enterprise' coherent solutions, perhaps, deeply dissected in their ICT peculiarities, yet loosely enabled in the production practices, requires

that, at least for a while, a bottom-up approach, entrusted from operation details, to academic envisions. Today, net concerns and world-wide-web are standard options, with shared acceptance in the current habits; e-communication, e-banking, e-market, etc. are every-day practice, with no especial denial or remark, when operating into loose contexts, out of cast about frames. The 'extended enterprise', the other way, faces formal demands, needing to follow more conventional approach, Fig. 3, in dealing with its functional organisation.

- the partners selection: the set of actors joins for the business opportunity, but responsibility, straight away, distinguishes producers from auxiliary providers, associated stakeholders and overseeing bodies;
- the competencies build-up: the trading of facilities/functions allows making ready the proper partner, at the right time and location, whenever the specific service is requested;
- the trust enhancement: the partners' involvement requires a hierarchic setting and there is no reason to share risk and profit, out of the individual duties/incumbents;
- the teamwork development: the company-spirit is hard to establish during ephemeral collaboration; thus, the aggregation rewarding is empowered by the contribution technical appropriateness;
- the legal formation: a special-purpose extended enterprise legislation does not exist; 'consortiums' or 'joint ventures' are, possible starting references, but the situation will quickly modifies.

**Fig. 3.** The extended enterprise functional organisation

In the meantime, the attention on technicalities suggests looking at 'virtual enterprises', say, organisations assembling the competencies build-up and assuring the 'externalities', namely, the PLM, the SE and the RL frames, each time requested by the 'extended artefact' supply, without, actually, reaching fully hierarchical structured deployment. The alternative is a factual alliance of partners, with obligations on the supply chain, at the lifecycle span, established by contractual agreements. According to the sketched formal approach, the 'virtual enterprise' setting is fostered by fitting options, Fig. 4, which shall ripen in the entrepreneurial lay-out. The picture is consistent with acknowledging the 'extended enterprise' lifecycle, more or less, as it is done by the 'extended artefact' lifecycle. The 'virtual enterprise' acts as a cluster of 'extended enterprises', which, each time, enables the requested competencies build-up.

- the trading of facilities/functions, to provide and manage the offers of partnership, enabling the net concern formation and up-dating, at low transaction costs and efficient legal protection;
- the integration support or broker aid, which acts, as net concern node or as external agent, for merging the demands and offers, and for assuring the on-process dynamic configurability;
- the education to virtuality, to make evident the advantages of dynamic net concerns, over static enterprise instances, when dealing with "externalities" out of the company core business.

**Fig. 4.** The virtual enterprise fittingness options

- responsiveness: a 'virtual enterprise' to play a role in the market shall be perceived as single company, or at least, a single member of the net concern should be identified as the 'extended artefact' responsible; this might become a problem, when no significant organisational supra-structure exists;
- legal personality: in a joint venture, every partner keeps its individuality, and a legal contract cannot be concluded by the ensemble, rather by single members, jointly or separately liable; the 'consortium' somewhat modifies the situation, with, however, restrictions on the partnership flexibility;
- global liability: the net concern efficiency is expected to come out from fitting worldwide partnership, by special enhancement from close-to-market partners; the clear agreement, upon which national law governs, should not hinder the actual manufacturers (this is important for most of low-price consumables, where free take-back incumbents could completely change the international trade competition);
- ephemeral character: if strictly dependent on the business opportunities, the 'virtual enterprise' instances come and go, conflicting with the life-support of most of durables; possible remedies are: insurance partners covering the lifelong delivery; a deposit/refund scheme to grant the "future" servicing, etc.;
- supply chain visibility: this requires multiple-range accomplishments, depending on the actual net concern set-ups, amid the PLM, SE and RL 'externalities', to cover operation/withdrawal service providers, to grant front-end users and third-people safeguard, to assure eco-assessment and remediation duties, and so on.

**Fig. 5.** The net concern characterising the functional choices

This suggests that the flow of the products along the manufacturing facilities characterises the traditional production processes; whereas the flow of the facilities along the product-service delivery assures competitiveness of the service-driven organisations. The market of facilities is fundamental prerequisite of the ‘virtual enterprises’; the role of brokerage and fair-trade aids has to be addressed to grant, both, SE and RL effectiveness.

### THE INTEGRATION CHOICES AND PROSPECTS

The extended/virtual settings do not differ at the backing information/communication frames. The bottom-up characterisation of the net concern leads to typical features, such as the ones listed in Fig. 5. The organisation merging develops over four different information sources: product-process-environment-enterprise, 2P2E, by the pace-wise amalgamation of functional models and performance assessments. The operation construal includes the related databases, Fig. 6.

- the standard product data: physical representation; operation performance, quality, cost and affordability; producibility; lifecycle requirements; use and maintenance directions; dismissal instructions;
- the standard manufacturing data: materials procurement and processing, assembly and disassembly; quality testing and conformance assessment; packaging; re-manufacturing;
- the standard environment data: voluntary agreements for low pollution and high remediation; mandatory targets to rule recovery (reuse, recycle) and safe dumping;
- the standard enterprise data: business functions: trading strategies, finance and resource management, etc.; operation functions: factory and facilities management, scheduling and planning, etc..

**Fig. 6.** The integration DBs for lifecycle consistency

- product design specification, leading to (CAD, CAM, etc.) construction files, to select producibility figures, duty constraints, disposal incumbents.
- manufacturing process specification, leading to improve factory effectiveness by simultaneous engineering aims through product-and-process mutual betterment, by means of pace-wise up-grading;
- delivery lifecycle specification, leading to define regulation, maintenance, restoring;
- entrepreneurship specification, leading to define the business policy, the productive organisation and the facilities selection.

**Fig. 7.** The eco-conformance by streamlined lifecycle assessment

The factual, trans-disciplinary approach leads to an integrated product-process-environment-enterprise, 2P2E, design, entailing operations in the four domains, to allow suited streamlined lifecycle assessment (SLA), of the delivery eco-consistency. The 2P2E design under SLA checks specifies the efficiently structured net concern, according to the enacted eco-targets on the four knowledge domains, Fig. 7, balancing manufacturing flow, to lifecycle and recovery demands. The process ends, acknowledging the ‘sustainable corporation’, i.e., the entrepreneurial settings having inner service-oriented organisation, which assures achieving lawful eco-targets.

### SERVICE ORIENTED INNOVATION

The eco-visibility supplied by the service-oriented is enhanced by the backdrop net concerns, exploiting the extended/virtual enterprise options, basically, because of three operation sources, Fig. 8.

- the virtual enterprise rulers or supply chain managers, which, from the devised business idea, integrate the facilities and organise the product-service delivery;
- the facilities/functions providers or (independent) actors having the skill and hardware/software potential to contribute the product-service delivery, at the given time;
- the fair-trade enablers, say, the market overseeing authorities, the brokerage supporters, etc., assuring set-up achievement and reconfiguration with responsibilities allocation.

**Fig. 8.** Backdrop aids for service-oriented eco-consistency

The ‘virtual enterprise’ rulers, supervised by fit govern agencies and aided by expert brokers, negotiate the configuration/reconfiguration of the business organisation with the chosen facilities/functions providers, so that, at each considered time, the organisation (productive set-up) assures high effectiveness to the ‘product-service’ delivery. At the background, spur comes from the PLM, SE and RL externalities; in the foreground, the integrated 2P2E design is enabled by the availability of the facilities/functions market. The sketched ‘servicing infrastructures’ are direct counter-part of the PLM, SE and RL ‘externalities’, which characterise the manufacture business to come. The required changes classify at different ranges, by respect to the traditional competencies, but, at the same time, present also different level of urgency. The PLM tools are established at the design stage, embedding

special purpose checks (e.g., lifecycle eco-impact appraisal); they are an extension of the manufacturers' knowledge and not of their activity (out-of data running). The SE provision shows explicit concern of product lifecycle; the company qualifies for further jobs, not embedded in the production cycle, but exploiting the knowledge, originally developed during the design, for enhanced return by 'product-service' delivery, mainly, ruled by voluntary agreements with the buyers. The RL duties appear in the EU environmental policy as mandatory targets, with producers' responsibility; the extension is enforced, and the service delivery, if not directly ruled, is anyway performed by somebody care (and profit), as the charges are required to be allowed to put a product on the market, [51–60]. The emerging research lines are, now, exemplified, looking at standard 'product-service' management at the lifecycle and at the end-of-life stages.

#### THE COMPANY'S ECO-QUALIFICATION

The 'sustainable corporation' specification is, in any case, starting pace aiming at the legal make-over of the sustainability targets, based on the eco-soundness visibility. The qualification of a company, to become SE supporter, in view to grant the remote proactive maintenance of the delivered items, is noteworthy goal of a 'extended enterprise', suitably structured by competencies and facilities for 'product-service' management. The approach is totally grounded on 'technical capital' tools, once the precise eco-targets are enacted over the entire global village. The depletion and pollution measurement and recording merely demands technical procedures, correctly specified and accomplished as engineering undertakings. The lifecycle conformance certification (LCC), is fair commitment, in coherence with the ecology globalisation. The corporation setting ought to programme manufacturing plans, in which the entire supplied products-services shall guarantee the befitting LCC levels, to bring out legal offers. The world over officialdom of factual 'sustainable companies' becomes suited answer; it also enjoys fitness, from economic viewpoints, meaning that the eco-consistence is mandatory prerequisite, engaging worldwide all the producers. From merely technical standpoints, the coherent eco-design progresses from 'lifecycle inventory' with suited 'product lifecycle assessment' (PLA). The procedure entails combined tools, currently described by changeful knowledge frames, progressively modified, when the eco-consciousness increases, still, basically resorting to

standardised computer aids, depending on the specialised tasks, listed in Fig. 9.

competing product-service choice, by streamlined lifecycle assessment (SLA) tools;  
product-service delivery, trimmed by computer aided lifecycle inventory (CALI) aids;  
lifelong monitoring, diagnoses and evaluations, done by PLM, SE and RL databases;  
setting of accredited/notified certification (ANC) bodies, for supply chain lawfulness.

**Fig. 9.** Servicing prerequisites of eco-consistent supply chains

The opening accomplishment starts by the 'streamlined lifecycle assessment' (SLA), using standard appraisal, capable of interfacing the 'product lifecycle assessment' (PLA), requirements with the whole PLM, SE and RL databases. One major goal is to detail the 'computer aided lifecycle inventory' (CALI) file, to accomplish the product-service delivery, unifying scope definition and impact evaluation. The standardised inventory has the scope of bonding the lifelong servicing and the supply chain specification. The information environment of the lifecycle 'eco-consistency' design and operation of the delivered supply chains properly shows the actual feasibility of the 'service economy' to come, based on extant technologies. The devised solution builds on bottom-up procedures, qualifying the market-operating companies bestowing lawfulness to their tangibles' manufacturing and trading. The framework is completed adding 'third party' controllers, independent on producers and users. This is 'big society' result, with resort to accredited/notified certification (ANC) bodies, which carry out devolved running, in lieu of the 'big state' handling. The setting reorganises as 'knowledge entrepreneurship', with suited operation hints, Fig. 10.

- to provide preliminary acknowledgements of these eco-conservative frameworks, in order to recognise the underlying requirements for growth enhancing;
- to suggest viable features for service engineering and inverse logistics for sustainable recovery, embedding data visibility and collaborative networked lay-outs;
- to outline the knowledge organisation of the business opportunities involving complementary stakeholders, and the enabling decision-making supports.

**Fig. 10.** Knowledge organisation for eco-service aims

This leads to hypothesis that a framed model, where the eco-consistency is faced by balanced in-

formation and communication frames, is capable to manage efficient resources preservation. The list of computer tools enters the accredited/notified certification (ANC) files, to help specifying the needed addition of third-party bodies, overseeing the 'sustainable corporations' and allocating fit lawfulness to their activity.

### LIFECYCLE/END-OF-LIFE RECOVERY MANAGEMENT

The compulsory RL duties, enacted by the EU for the recovery of specific durables (such as ELV, end-of-life vehicles, WEEE, waste electric and electronic equipment), are instances, in which the 'service frames' have to be made ready, as inherent accomplishment of the supply chain. In these areas, the reference to 'extended artefacts' cannot be ignored; the manufacturer competitiveness will forcedly turn to integrated 2P2E design, unless, for the set of properties, fully covered by mandatory targets from existing regulations. The ELV and WEEE cases, already, represent a very huge business that cannot be postponed, even, whether the domain producers are not yet service-oriented, to deploy 'extended enterprises' layouts.

- within the production process: suitable antipollution regulations are issued at process/facility levels, and promotion of conservative design is fostered by, e.g., the Eco-design of End-use Equipment, EEE-directive, through a series of advices and warnings;
- along the supply on-duty cycle: eco-consistency figures, included in the construction file, need to be strictly followed, to reach conformance-to-use assessments; then, fitting service engineering, grounded on ambient-intelligence, comes out as winning opportunity;
- from the product disposal: today, most of durables, and in a short future, the whole consumables need to fall within suppliers' responsibility, under to the free-take-back scheme, aiming at reverse logistics treatments for resource recovering and dump avoiding.

**Fig. 11.** Example clues for manufacturer/supplier liability

Then, the 'virtual enterprise' by-pass ought to be investigated, at least, as temporary and local option. The ability of assembling proper net concerns, in view of a business opportunity, as above pointed out, depends on: the deployment of a facilities/functions market; the availability of integration or broker support; and the 'education to virtuality'

according to effective service management rules. The three aspects deserve proper support. The different regulation acts look after establishing eco-costs, to be included in the (tangible) goods, when brought into market. These costs need to include cleaning up, reclamation and consumption ratios, and will represent a sort of threshold tax, collected from producers/importers and dealers, to refund the supply chain burden, due to the inherent falloffs. Some example hints are given, referring to the three phases, planned by the EU Directives, Fig. 11. The ELV and WEEE demands require throughout changes of the industry surroundings, with huge fallouts in research and development structures and in market regulation, such as the ones listed in the Fig. 12.

- ▶ direct investments by manufacturers, to switch product competition into recoverability figures;
- ▶ restructuring the reverse logistics business, into high-tech efficient reuse/recycling companies;
- ▶ creation of producers/dismantlers/recyclers clusters, with collaborative networked-organisations;
- ▶ growth of certifying bodies, to manage the economic instruments, under the EU mandatory acts.

**Fig. 12.** Example fallouts of recovery/reclamation duties

- ▶ tax on virgin materials or subsidies on recycled stuffs, paid at provisioning or at recovery (possible distortions on primary/secondary materials market, unless global legal metrology prices are stated);
- ▶ landfill charges, paid for waste dumping (possible negative effect: illegal dump);
- ▶ recycling fee/credit, paid by artefacts buyers and transferred to subsidise recycling (possibly profit for reverse logistics operators);
- ▶ deposit-refund, paid by first buyers and returned to the last owners at dismissal (possible negative effect: illegal trade of end-of-life items);
- ▶ free-take-back, included in the price of new artefacts and used by producers to subsidise recycling (possible profit for manufacturers).

**Fig. 13.** Example repayments of resource withdrawals

When dealing with the manufacturer/supplier responsibility, the extant depletion/contamination refund takes into account a few chances, Fig.13, each one affected by induced drawbacks. For the policy makers, the service economy, basically, requires the bottom-up qualification of the front-end 'sustainable corporations'. The standard knowledge includes the above listed prerequisites and options, from the 2P2E design, to the purposefully developed service-oriented computer aids.

## CONCLUDING COMMENTS, FUTURE PLANS

The ‘sustainable growth’ is bet, more than certitude. In the paper, the backdrop looming threats were recalled, not investigated, since their general features were well known outcomes of the ‘ecology’ globalisation, already well assessed by recent examinations. Even if the present survey, typically, limited to engineering statements, the ‘eco-service’ prospects were viewed in the more enthralling context of the ‘cognitive revolution’, which is necessary, once recognised the ‘industrial revolution’ drawbacks.

Then, to figure out general rules answering the ‘sustainable growth’ demands, a bird-eye analysis of the ground-breaking variations to come was, initially, given, to provide evidence of the main standard knowledge, requested by policy makers and research leaders. The hints were combined into huge listing of ‘suggested readings’, knowingly inserted, to show that today mankind is at a civilisation turning point [61–70].

The investigation purposes were to, thus, exploit the general ecology demands, to make understanding that inclusive changeovers are compulsory, once looking at mitigating the over-depletion/contamination outcomes, by the lifecycle reclamation of the on-going processes, through suited service allocations. The wide-ranging goals of the study defined the main trends, Fig. 14, of the human civilisation adventure, to elucidate the in-progress value added deployments.

At the special purpose engineering concern, the servicing changeover is noteworthy innovating opportunity. The integrated 2P2E deployment permits to extend the supply chain coverage, aiming at consistent delivering ‘products-services’, under the unified responsibility of companies or clusters of facilities which exploit net infrastructures and ‘virtual’ organisations, to create the effective service-provider, whenever given business opportunities establish, according to voluntary agreements or to mandatory targets.

The prospected research activity is necessary prerequisite of the coming manufacture market; referring to ICT tools, including a few specific chances, Fig. 15, supplied by suited computer aids.

the oddity of the adventure of men, trusting their planning and proficiency talent;  
 considerations on the backdrop: science issues, picturing our earth and universe;  
 considerations on the actors: civilisation endings, rooted in intelligence originality;  
 survey of the mainly social advancements, grounded also on history achievements;  
 survey of the basic politics and economics frameworks, to derive continuity hints;  
 the awkward trial of sustainability prerequisites for a hoped cognitive revolution.

**Fig. 14.** Main peculiarities of the men adventure

► the information architecture for data exchange, access handling, security management, contingency ruling, etc., with operation agents (local units, network servers, archives managers, search engines, security tutors, etc.) and distributed services (access, messaging, etc.) with storages (catalogues, databases, etc.);  
 ► the support mechanisms and tools for the net concern overseeing, as, by itself, the net is not enough, and it requires the interoperability, the resources integration and co-ordination, the performance monitoring and evaluation, etc., to feed the stakeholders with the pertinent operation visibility;  
 ► the lifecycle transparency of the dynamic ‘virtual’ corporation, covering the phases of creation, operation and dissolution, so that the market of facilities/functions, through the differentiated offer/demand partners, keeps leading role in the negotiation of optimally suited arrangements.

**Fig. 15.** Example options enabled by ICT tools

These example technical aids are the issue of trans-disciplinary advances, when the entrepreneurial business can incorporate the fitting net concern technologies, addressing the new developments towards exploiting the facility and function integration, into extended/virtual enterprise sceneries. The lifecycle eco-service comes out to be business opportunity, rooted in compulsory ‘lawfulness’ schemes, yet, efficiently buttressed by the existing net concern infrastructures. This survey helps sketching the prospects at an engineering standpoint; the socio-political discussion of the topics requires further deepening: the ‘suggested reading’ list shows that wide diagnoses and projections are already available. This paper contains several engineering, human, and even political and philosophical hints and ideas, however some kind of methodology, quantification, measurements and calculation possibilities are still open and need further



studies to properly evaluate behaviours and situations and relationships.

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#### METADATA

**Title:** Life-Cycle Eco-Services for Sustainability

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**Abstract:** The paper addresses the sustainable growth, or even better: 'sustainability' as a challenge for tomorrow, to assure progress continuation. From engineering viewpoints, the bet has to be accepted, and the 'service economy' provides valuable hints, affixing chances, with innovative worth. Pertinent details are specified, with links to the net concern deployments. The paper gives a survey and some genuine ideas to understand some crucial problems of mankind, which were out of scope for several hundreds of years and became important – at least some people started to understand and explain only in the second part of the previous century, namely problems of ecology, of environment, of expectable en-

ergy and material shortages, including drinking water, which all together led to the acceptance of sustainable growth and then of sustainability. Sustainability may mean our survival from technical and social point of view as well. The importance and management of services – besides the production – will be discussed in details. Personal and company level issues will be analysed, as well as international and European Union level problems and solution efforts. Life-cycle management of traditional and extended (virtual) organizations, and the tangible and intangible properties and views of all types of objects are discussed, too.

**Key words:** current industrialism, progress, service engineering, virtual settings, integration choices, prospects, future plans

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