37 INFORMATION INFRASTRUCTURES AND SUSTAINABILITY

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Today sustainability is a basic demand. It often contradicts with the needs of an affluent society. The life quality of industrial countries could never lower, if trading of extended *artefacts (*products-services*) will be based on exchanging information-intensive deliveries. The wealth build-up will follow in the knowledge society, fostering eco-consistent behaviours by balancing tangibles decay by intangibles increase. The idea is described by the KILT model, which characterises by the TYPUS metrics. The paper discusses some topics of the prospected scenario, underlining supply chain issues, showing that the ICT options are critical aids to create the required information environment. Some basic trends are sketched, focusing on products-services trading, supplied by extended enterprises, under supervision of independent certifying bodies.*

1. INTRODUCTION

Sustainability (James, 1997) is a new challenge. Until now the industrialized countries, profited by the haphazard consumption of tangibles to widen the *manufacture* market. The *affluent* society tries new offers to out-date the previous ones; wealth generation stresses on quantities, as factories return increases by selling greater amounts of wares, to supply items at prices that greater number of buyers can afford. Market saturation and technology options, recently, turned rivalry to *scope* economy, to supply items at client's satisfaction, exploiting plants' flexibility to manufacture market-driven mixes of items. The change is consistent with simultaneous engineering, which leads to the merging of design and fabrication into *intelligent* organizations (Ettlie, 1994; Michelini, 2001 and 2001a). The welfare growth of industrialized countries, thereafter, aims at the *service* market (Michelini, 2002), by supply chains jointly embedding *commodity* and *utility* provision.

The *extended* artefact (*product-service*) blends *commodity* and *utility*, by information intensive delivery to grant specified *functions*. *Consumables* (raw materials and grown or manufactured commodities), have prevailing birth from non-renewable sources and, as the earth is a closed system, development sustainability shall asymptotically cause wealth downgrading, unless the staple turns to yield value chains into *intangibles* (knowledge, technology, etc. with services, functions, etc. delivery). The result depends on the *information technologies*, believed to be able to strengthen and unfold the paradigm shift to *scope* economy, with changes in habits: *knowledge-* vs. *tangibles*-marketing, leading to eco-consistent progress, without lowering welfare by proper balance. This scenario is worth to be investigated in the following way:

- we shall explore the ***KILT*** model (see later on) to work out sustainable quality features (***TYPUS*** metrics) and coherent support (*net-infrastructures* or *collaborative* networks) needed to fulfil the paradigm shift to eco-consistency (*method* innovation);
- then the analysis considers the technicalities for thrifty achievements through *extended* artefacts and extended enterprises, once the ***TYPUS*** metrics charges consumers for resources decay: backward cycle factories, third-party certifying bodies and *product-service* business are main falls-off.

The *information technologies* are instrumental aids, directly and indirectly affecting sustainability by pervasive provisions. In the switch from *affluent* society (*consumables*) to *thrifty* society (*intangibles*), the technical-scientific patterns only represent necessary prerequisites. Legal-political and socio-economical patterns need to be established, too.

2. FROM AFFLUENT SOCIETY TO THRIFTY SOCIETY

Earlier we used to deal with invested capital (I) and/or involved labour productivity (L); these remained for a long while the only chief factors affecting manufacture delivery (Q). Recent assessments show that the relevant role of a third quantity, knowledge (K: know-how, technology, expertise, etc.), leading to value chains increases up to 40-50 % or more. At the millennium turn, ecology concerned people require to stop free access to non-renewable resources, with profit for manufacturers and purchasers and damage for present and future population. Basic claim is to refund the leftover humans for the tangibles decay (T) diverted along the supply chain. Thereafter, the manufacture delivery (Q) will depend on four independent factors (K, I, L and T) (Michelini, 2002 and 2001a):

$$\boldsymbol{Q} = a_0 \boldsymbol{K I L T} - a_1 \boldsymbol{K} - a_2 \boldsymbol{I} - a_3 \boldsymbol{L} - a_4 \boldsymbol{T}$$

where: ***K***, knowledge and technology; ***I***, invested capital; ***L***, labour entry; ***T***, consumed tangibles, as mentioned above.

The ***KILT*** model assumes that the four (scaled) factors have similar effects and that the lack of any of them brings to negative built-in delivery. The direct dependence on an individual factor characterizes clustered companies, which resort to non-proprietary technologies, venture capitals, outsourcing or leased provisions to keep the business work. Four productivity figures, accordingly, appear, and *fair* competition needs *equal opportunity* players.

The explicit dependence on ***T*** and the request to repay for tangibles depletion are coherent with sustainability goals. The challenge aims at drastically lowering downgrading, still preserving welfare: the scenario looks after *knowledge* society surroundings, where *extended* artefacts (*products-services*) are traded by *extended* enterprises (*nested infrastructures*), so that the supply-chain grants a ***K*** factor value, properly balancing the extra costs paid for the ***T*** factor.

The innovation brought forth with explicit account of the ***K*** factor leads to the *knowledge* society; it does not mean overcoming the *affluent* society. The uneven distribution of wealth among the world countries shall simply modify with higher profits localized within the knowledge-intensive ones. The economic bias will not, repeat the trends arose in the past, by ***I*** or ***L*** factor built-ups, due to ***K***-trade peculiarities, shortly mentioned in section 3. The *thrifty* society foundation establishes on the further explicit account of the ***T*** factor, again, with peculiarities not repeating known patterns.

2.1 The TYPUS Metrics

The explicit inclusion of natural resources spoilage in pricing life-cycle artifacts should be based on worldwide accepted standards. The exact amounts represent a public income, with twofold goal: to remunerate the people not involved by the specific transaction, and to spur thrifty choices either to hinder squandering. The other side, no intention aims at hampering or stopping the progress, rather at modifying the staple in consumables by enhanced focus on renewable (natural) stuffs and re-cycled commodities. The approach requires worldwide withdrawals for tangibles decay, with equivalent tax burden, objectively linked to the life cycle of every traded artefact, including overall provisions and dismissal opportunities. On these ideas, several metrics can be proposed, with figures stated within the acknowledged legal metrology precepts, on condition to have full *visibility* on the artefact life-cycle data and proper *control* on the actual operation falls-off.

In any case, the definition of measurement standards is a preliminary fulfilment. A coherent answer looks after defining a framework, which gives account for the all material-and-energy flows activated along the considered artefact life-cycle and assumes that the net depletion is assessed at the life-cycle end, including side-effects to remove negative impacts and positive contributions due to recycling and recovery. The idea leads, typically, to the ***TYPUS*** (*tangibles yield per unit of service*) metrics. The framework is built on the assumption that most buyers are primarily interested in the *functions* delivered by the instrumental artefacts they purchase, thus a scale based on the *unit of service* is specially relevant to turn users to conservative behaviour, as pricing the *tangibles yield*, more than abstract quality figures, shows that actual needs are favoured.

The *collaborative* network presumed by the ***TYPUS*** metrics is a challenging development where highly structured ICT tools are available. We might look at prospected standards from two viewpoints:

- the short terms preparatory practice, to help introducing *costs* for the actual decay of tangibles;
- the longer terms habits, to foster the agreement on the *scope* of maximizing ***T*** productivity.

2.2 The Collaborative Networked Support

The ***TYPUS*** metrics needs suitable *collaborative* networks to manage the life-cycle data, within transparent and scrupulous facilities. The arrangement basically requires three facts: the marketing of *extended* artefacts, the involvement of *extended*

enterprises and the overseeing of third party certifying bodies. On these conditions, information nested infrastructures are basic aids:
- to provide collaborative forms and behaviours for product life-cycle management;
- to rule conformance assessment and restoration within networked responsible bodies.

Thus, the network has direct links with "conventional" *extended/virtual* enterprise implementations. The *collaborative* network complexity appears highly tangled, as several firms are involved, through competing offers to manage equivalent *product-service* settings. Thus, interlaced *net-infrastructures* shall exist within almost worldwide contexts, and need grant the protected access to the *extended* artefacts' life-cycle databases, from the overseeing certification bodies. This, within the many achievements of the *knowledge* society the ***TYPUS*** metrics (or an equivalent reference) cannot operate without the full visibility on the artefact life-cycle, with all related beforehand, side and afterwards effects.

2.3 The Role of Method Innovation

The *knowledge* society is viewed to the winning path to the *thrifty* society, providing technical aids, directly by the mixed utility-commodity ICT provisions, indirectly by supporting the *extended* artefacts market. The technology-driven issues are not *sufficient* to generate sustainability. Today, the purchasing decisions that favour a *product-service* with lower impacts in resource provision, in life-cycle use, etc., with properties that facilitate reuse or recycling, etc. are qualitative spurs; resource productivity (***TYPUS***) is an hypothesis: no established standard is available; no testing and overseeing body exists. The proposition looks after three aids (Binder, 2001; Graedel, 1997; Giarini, 1998):
- technical-scientific support of innovation by targeted R&D projects
- socio-economical promotion of the appropriateness of eco-consistent behaviours
- political-legal actions by means of the governmental regulation of eco-compatibility

The relevance of the legal and social (beside technical) conditions for *method* innovation stems from the current refusal of alternatives: engineers are *manufacture* economy minded; consumers belong to, possibly, even less receptive areas. The thesis that people is more interested in *using* goods and profiting of *functions*, than in possessing items, is dubious; more questionable that ownerless consumption leads to eco-benefits: leased items, e.g., may age faster than owned one, due to the lessee's irresponsible use in wear-out protection and up-keeping carelessness.

3. EXTENDED ARTEFACTS AND ENTERPRISES

Only some technical aspects are investigated, even if we know that socio-economical and political-legal contributions are fundamental, too. Central role is played by the *extended* artefact *(product-service)*, i.e. instrumental (tangible and intangible) delivery to a client, granting the enjoyment of specified *functions*, according to life-cycle indenture. The *extension* obliges the supplier to the user for conformance assessment at the point of service, both being bound by enacted (safety, environment, etc. protection) rules.

The main actor in the *extended* artefact market is the *extended* (recently often called as virtual) enterprise or *net-infrastructure*, i.e.: factual alliance of partners merging skills, know-how and resources and enabling co-design, co-manufacture, co-market, co-maintain, co-servicing, co-recycle, etc. efforts, to offer *extended* artefacts at purchaser's benefit *and* environment safety (Graedel, 1997). The *extension* provides visibility on *products-services* operation life to support:
- resources consumption and surroundings impact recording;
- third-party conformance assessment and eco-figures certification.

The *extended* artefact and enterprise definitions assume that *method* innovation is the main concern and ***TYPUS*** metrics in included within the economy of *scope* patterns, according to so called, longer terms habits.

With focus on *extended* artefacts (Thoben, 2001) the critical opportunity is to enable the practice of technological *sustainability* (James, 1997; Mirchandani, 1996), by moving welfare generation from a typically *manufacture* market, to a mainly *function* market. The *extended* enterprise case is slightly different, as ICT is critical there. Although the expected advantages of interconnected infrastructures are properly recognized, existing tools suffer drawbacks, as lack of common reference models to be shared as *type*-facility; lack of effective interoperability mechanisms and approaches; lack of eligible protocols and frames, free from non owned details; heavy design and engineering efforts to make proprietary technologies co-operate; rapid software and hardware obsolescence, frustrating provisional goals; actual obstacles in the effective transfer of locally tested instruments; and the lack of viable leadership proposing low-cost linking environments.

3.1 Supply Chain Management Issues

Today the world-wide globalisation and the appearance of extended/virtual enterprises require more than only Supply Chain Management (SCM) for some tasks of a given enterprise. Due to the physically and logically distributed character of the co-operating units (workshops, plants, enterprises, etc.), taking advantage of the existence of global networking, web-based solutions are suggested. There were two EU projects (FLUENT, 1998 and WHALES, 1999) that provided such solutions. (FLUENT, 1998) gives "beyond SCM" workflow/supply chain solutions for distributed (mainly SME) organizations dealing with manufacturing, services, maintenance, etc. The main target firms of (WHALES, 1999) are the distributed, multi-site, multi-firm, powerful organizations (and SMEs), and the goal is to manage complex, one-of a kind products and projects, manufacturing and management as well.

The results provide new IT solutions for managing complex logistic flows, occurring in distributed manufacturing networks with multiple plants and co-operating firms. Networks of this kind are gaining relevance and diffusion, under the impulse of the following main factors:
- emerging virtual/extended enterprise paradigms
- pull-oriented production models, like just-in-time, requiring synchronisation of internal and external flows
- lean/agile manufacturing models, based on horizontal, goal-oriented process chains
- evolving market conditions, calling for business globalization and decentralization of manufacturing facilities.

Traditional SCM implementations refer to a linear, standardized and relatively stable view of the supply chain: "supply chain management is about managing the flow of products and services and the associated information, across the whole business system to maximise value to the end consumer." (Price Waterhouse, 1997).

Recent analyses have pointed out the potential failure behind the traditional, linear logic, especially where revenue increase is pursued instead of cost reduction:

- Cost reduction leads to: standardisation and simplification of supply chain and its operation; minimization of integration costs; definition of "functional silos" independent of each other.
- Increasing revenues means to take advantage of diversification and differentiation, exploiting changes in demand and supply. This means making more money thanks to the supply chain ability to reconfigure itself, to harmonize capacities and to respond quickly as a whole.

To look at the supply chain complexity as a competitive advantage, rather than as a source of costs, means a radical change of perspective in the organization models supported by SCM tools: "For a start, the supply 'chain' is really not a chain at all - it is a complicated web of relationships between demand and supply. The concurrent and multidimensional nature of these relationships creates a complex fabric, woven step by step."(Mirchandani, 1996).

The logical architecture of a new network of an extended enterprise means some nodes equipped with the new system, other nodes are acting as customers, suppliers or subcontractors. Nodes of the latter type can only take part as executors in logistic flows controlled by the flow management nodes. The reason is that these nodes lack the network-level vision and decision support tools to actively participate in the planning and co-ordination of supply flows.

Each node is perceived by the other nodes as an autonomous source of: (i) information on the node and the goods it supplies and consumes (*knowledge* level); (ii) demand/availability signals and allocation decisions (*planning* level); (iii) supply control signals and exceptions (*control* level). Independently of ownership and position in holding hierarchies, nodes in the network are modelled as source and destination of logistics flows. To this purpose, each node is attributed a three-tiered structure including: a Flow Collector, that manages incoming logistics flows, a Flow Dispatcher, that manages outgoing flows, and a Flow Processor, responsible for integration with internal production flows.

Co-operation between nodes is realised through links, each representing a stable relationship for the exchange of a given product between a "supplier" node Flow Collector and a "receiver" node Flow Dispatcher. The Flow Processor is not directly involved in the link, since the flow control is based on a clear separation of logistics decision-making domains. Internal logistics are managed by each node on its own, and are perceived at the network level only through requirements, events and constraints on external logistics flows. A link definition fixes the characteristics of supply flows taking place through the link, in terms of:

- data on the supplied product, including shipping, transportation and delivery parameters
- planning policy applied to the link, in terms of planning parameters, planning method, e.g., "push" or "pull", and planning responsibility, e.g., either the supplier or the receiver, or a third node controlling the flow

- workflow model, i.e., the sequence of messages and events characterizing the nodes interaction during planning and control of supplies over the link.

This way, a high degree of generality and flexibility is reached in modelling the variegated network configurations found in the real world. For example, a node can establish "pull" links with a network of suppliers, keeping a centralized control of suppliers selection and orders allocation. The node product can be delivered to a trading partner on the basis of an inventory replenishment agreement, modelled by a "push" flow controlled by the supplier, and to a customer on the basis of a normal "pull" link. Both types of outgoing flows can originate dependent requirements for the above suppliers network.

3.2 The Backward Cycle Business

The backward cycle deals with parts and materials processing after (partial or total) dismissal of the handled commodity. Nevertheless, as we are concerned by extended artefacts, the information contents are not neutral and two restricting patterns establish: • feedback of forward cycle features, to recognise the appropriate design-for-specifications; • forecast of backward cycle features, to include suitable design-for-recycling specifications.

The backward cycle is simply an option, to be weigh against others, when eco-design becomes a main purpose, so that focus scans on: • planning for quality protection, disassembly, material reuse, etc.; • designing for long-life, rare maintenance, low energy consumption, etc.; • preferring self-tuned rigs, re-used packaging, improved logistics, etc.; • setting optimal effectiveness, pro-active up-keeping, etc. artefacts; • choosing high throughput, material saving, energy recovery, etc. cycles; • making use of recycled, less energy-intensive, renewable, etc. materials. After dismissal, re-conditioning or re-manufacturing are relevant options:

- re-conditioning has the goal to back establish overall conformance to specification, by combined industrial processes addressed to artefacts at their life end; re-conditioning is limited, if re-setting is partial;
- re-manufacturing recovers parts and material with properties matching the original ones, by combined industrial processes applied to dismissed artefacts, and candidates them to new duty-cycles; the issue is limited, if the processed parts do not recover the original characteristics.

When new artefacts are conceived, the backward cycle affects original choices to include re-conditioned and re-manufactured items and to forecast careful set-ups for recycling. However, the integrated design steps are not sufficient, by themselves, to grant economical return; the thrifty society surroundings, actually, establish when the artefacts true price includes the overall cost for materials and energy depletion suffered by the eco-system; thereafter, the world-wide use of the **TYPUS** metrics, or equivalent taxing procedure, will be enabling reference for the backward cycle, at the different ranges of the forward one.

3.3 The Conformance Assessment

Taking the life-cycle into account, alternatives are possible, once extended artefacts are supplied by extended enterprises and third party certification bodies oversee the life-cycle incumbents. The three parties ruling seem to be a good compromise to enhance competition and to balance responsibilities, under real fair-trade conditions.

The picture is coherent with a controlled collaborative network, directly linking an extended enterprise to individual clients, so that the supply chain of each delivered extended artefact is transparently available.

The relevance of the conformance assessment service shows that this new business might grow to large percent of the gross national product of each country, becoming a wealth source of the knowledge society. The involvement of third party certifying bodies needs, of course, proper regulations, enacted by the national authorities, but suitably harmonized to assure worldwide equivalence.

Certifying bodies compete in a free market, being replaced possibly any time, exactly as the partners of an extended enterprise, or the agreements about the extended artefact responsibility might be up-dated. The changes do not interrupt supply chain monitoring, simply request that the new entries are accepted by proper data transfer, and the new duties are assigned.

3.4 The Falls-Off on the Manufacture Market

The build-up of backward cycle enterprises and of eco-certifying bodies can progressively establish on existing patterns, drastically expanding the business domains and enhancing the collaborative network aids, to fully achieve the method innovation of the thrifty society. The technical opportunities are mainly provided by ICT instruments, and correspond to focus, for fixed deliveries on specialising the web links of extended enterprises to individual resources utilization requirements (Price Waterhouse, 1997; Mirchandani, 1996) in a way that, even in front of defective cross-link occurrences, decisive helps establish along finalized patterns, to help the surfacing of filtered knowledge (whether the series of consents verify for the selected tracks), leading to a set of tailored provisions, such as: - interoperability by integration and sharing of federated information; - management of distributed activities, based on self-acting clusters; - supply-chain transparency given by eco-consistency assessment records; - goal-oriented co-operative knowledge problem-solving capability; - sectional bounded and case-driven trust building processes. These and similar contrivances contribute to the coherence of the collaborative network.

The evolution brings to supply chains jointly embedding commodity and utility provision, so that the value of intangibles becomes prevalent as compared to the one of consumables (whether non renewable resources are concerned). The scenario is not new, as the boasted merit of industrial society was the delivery of low price artefacts, as compared with people wealth, based on wide resort to natural raw materials. After a while, this becomes a deceitful virtue: alternative provisions need to be explored for the value chain of artefacts to avoid squandering earth treasures. The knowledge society might be a winning answer, grounded on selling information and assuring high revenue based on intangibles. The out-coming market presents some peculiarities: trading information will never dispossess the dealer of his original know-how; sharing information is based on individual commitment and does not automatically follow from paying for it; developing information is typically non-linear process, grounded on synergic accumulation; augmenting information could be costless, whether built on collaborative settings with additive specialisation; and so forth. The extended artefact supply chain represents a challenging bet, and the falls-off on the manufacture market could bring to the thrifty society, with the many facets we have tried to sketch in this study.

4. CONCLUSIONS

The paper moves from the recently acknowledged KILT model (Michelini, 2001 and 2002b), and - among others - arrives to the TYPUS metrics (Michelini, 2002b). It should be said that, by now, eco-consistency already looks after specially-enacted resource-duty collection systems (Kyoto protocol, carbon tax, etc.), thus the approach is coherently generalised by means of the TYPUS metrics, to establish world-wide taxation settings for fair trade preservation. For sustainability, the affluent society, supported by ceaselessly replacing artefacts, needs evolve to the thrifty society, based on carefully sparing natural resources. This would quite obviously leads to notably lower welfare, unless alternative contrivances are sought to build up wealth. Now, ICT aids are paramount opportunities, which add to established instruments that mankind disposes to protract his progress. The ICT tools characterise the knowledge society, stressing on totally new goods either deeply modified artefacts, by up-graded information contents, so that relevant paradigm shifts apply to the common manufacture practice and to the current consumers' habits. These paradigm shifts are addressed in the paper on, mainly, technical viewpoints, even if legal-economic factors critically affect their feasibility and actual falls-off are properly related to complex issues in the extended artefacts market, generally referred to as *method* innovation. The prospected issues, in fact, depend on exploiting knowledge-driven options by networked set-ups, to manage the supply-chain and embedded information flow, through extended enterprises. The study has the goal to turn the European scientists to the emerging fields of eco-consistency, to take a lead in pioneering objective quantitative assessments of the environment suffered impact, while tangibles are traded to satisfy consumers' requests.

Sustainability growth, indeed, shall first address broadband eco-compatibility goals, assuming that transition to the thrifty society requires changes in habits even before than technical innovation. According to the suggested research lines, the TYPUS metrics should be strictly grounded on scientific principles and technical standards; the visibility of tangibles consumption, then, will be assured by jointly enabling extended artefacts and extended enterprises. This will lead to a different concern in front of natural resources spoiling, with drastic changes of the industrial organizations, supporting the new business of the backward cycle (from dismissed scraps, to recovered materials). The existing welfare, on these ideas, rather than decreases, could widen, recovering by K-growth, the taxes paid for T-decay. The scenario, however, requires:

- technical-and-scientific innovations, to grant the overseeing and the control of artefacts up to dismissal, with life-cycle recording;
- socio-economical assessments, to prove the return on investment of eco-conservative behaviours and the benefits of method innovation;
- political-and-legal changes, to extend the providers responsibility to the point-of-service, for community protection and tax collecting.

The build-up of bylaws, rather than neutral, will be a spur toward sustainability, giving transparency of the performance between competing solutions. The eco-qualified factory, with extended-artefacts, increases its market share, based on information extended infrastructures, advertising the eco-consistency by connected frames, binding, at the points-of-service, suppliers and users with accredited certifying bodies, under world-wide regulation acts.

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