Profit from waste using systematic innovation methods

Darrell Mann
Systematic Innovation, UK

ABSTRACT

The Russian instigated Theory of Inventive Problem Solving, TRIZ has much to offer 'profit from waste' industry sectors. The paper describes a TRIZ-based systematic innovation methodology and its ability to generate innovative new solutions to a variety of waste management problems. Case studies described include conception of novel bio-mass combustion systems, application of TRIZ tools to the development of a novel thermo-electric-generator for use in remote site schemes and application of TRIZ trend prediction tools to identify future waste management profit-making opportunities.

INTRODUCTION

Changes in legislation and public perceptions about waste mean the industry has to think differently about how it conducts its business. Effective innovation is becoming central to future success. Traditionally, however, innovation has been equated to 'high risk', and many organisations have been reluctant to devote precious resources to developing innovative new products, processes or services.

The recent introduction of systematic innovation methods into the UK looks set to change this picture. Central to these new methods is the Theory of Inventive Problem Solving, TRIZ, a series of tools and strategies developed through over 1500 person years of research and the study of nearly three million of the world's strongest patents.

The key findings of TRIZ research are:-

- that all innovations emerge from the application of a very small number of inventive principles
- that technology evolution trends are highly predictable
- that the strongest solutions transform the unwanted or harmful elements of a system into useful resources.
- that the strongest solutions also actively seek out and destroy the conflicts and trade-offs most design practices assume to be fundamental.

The paper presents a TRIZ-based problem definition and problem solving methodology that is now being successfully deployed across a broad spectrum of fields and problem types.

The first section of the paper examines TRIZ from the perspective of the paradigm shifts and emphases that make it deployable in the context of a working environment previously unfamiliar with the method. Subsequent sections then go on to describe how TRIZ is being integrated with other systematic innovation methodologies, and how the combined methods are beginning to be applied successfully to a number of 'profit from waste' relevant problems. A final section of the paper predicts future industry trends based on analyses using the trends of evolution uncovered by TRIZ researchers.

TRIZ BASICS

TRIZ provides means for problem solvers to access the good solutions obtained by the world's finest inventive minds. The basic process by which this occurs is illustrated in Figure 1. Essentially, TRIZ researchers have encapsulated the principles of good inventive practice and set them into a generic problem-solving framework. The task of problem definers and problem solvers using the large majority of the TRIZ tools thus becomes one in which they have to map their specific problems and solutions to and from this generic framework.

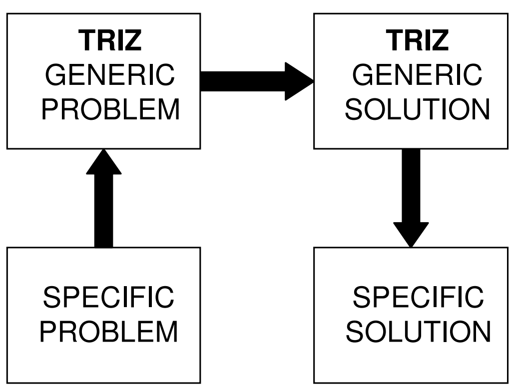

Figure 1: The Basic TRIZ Problem Solving Process

By using the global patent database as the foundation for the method, TRIZ effectively strips away all of the boundaries which traditionally exist between different industry sectors. The generic problem solving framework thus allows engineers and scientists working in any one field to access the good practices of everyone working in not just their own, but every other field of science and engineering.

THE FOUR PILLARS OF TRIZ

1500 person years of TRIZ research have produced a significant number of innovation tools and methods. The method allows users to deploy each of these tools in either an individual or systematically sequenced manner. References (1) through (5) offer interested parties means of finding out more about TRIZ. This section offers a brief summary of the four main elements that make the method distinct from other innovation and problem solving strategies.

Contradictions

TRIZ researchers have identified the fact that the world's strongest inventions have emerged from situations in which the inventor has successfully sought to avoid the conventional trade-offs that most designers take for granted. More importantly they have offered systematic tools through which problem solvers can tap into and use the strategies employed by such inventors. The most commonly applied tool in this regard is the Contradiction Matrix – a39x39 matrix containing the three or four most likely strategies for solving design problems involving the 1482 most common contradiction types. Probably the most important philosophical aspect of the contradiction part of TRIZ is that, given there are ways of 'eliminating' contradictions', designers should actively look for them during the design process.

Ideality

While studying the patent database, TRIZ founder Genrich Altshuller identified a trend in which systems always evolve towards increasing 'ideality' and that this evolution process takes place through a series of evolutionary S-curve characteristics (1, 6). A key finding of TRIZ is that the steps denoting a shift from one S-curve to the next are predictable. A number of underlying technology evolution trends consistent with the ideality concept have been identified during the course of research on the global patent database. Used as a problem definition tool, the ideality part of TRIZ encourages problem solvers to break out of this type of thinking, and rather start from what is described as the Ideal Final Result (IFR). The simple definition of IFR is that the solution contains all of the benefits and none of the costs or 'harms' (environmental impact, adverse side-effects, etc). While the tool may be seen in this light as more of a theoretical start point than a viable solution generator, it is worth noting that the uncovered technology trends offer highly practical ways of generating IFR-oriented solutions. Generally speaking these solutions incorporate the concept of systems solving problems 'by themselves'. The key word is 'self'; things that achieve functions by themselves – self-cleaning, self-balancing, self-heating, self-aerating, etc – all represent, when incorporated in a true TRIZ fashion, very powerful and resource-efficient solutions (7).

Functionality

Although the functionality aspects of TRIZ owe a significant debt to the pioneering work on Value Engineering, the method of defining and using functionality data is markedly different; sufficient at the very least to merit discussion as a distinct paradigm shift in thinking relative to traditional occidental thought processes. Three aspects are worthy of particular note:-

1) The idea that a system possesses a Main Useful Function (MUF) and that any system component which does not contribute towards the achievement of this function is ultimately harmful. In a heat exchanger, for example, the MUF is to transfer heat to the working medium; everything else in the system is there solely because we don't yet know how to achieve the MUF without the support of the ancillary components. (Systems may

of course perform several additional useful functions according to the requirements of the customer.)

2) In traditional function mapping, the emphasis is very much on the establishment of positive functional relationships between components. TRIZ places considerable emphasis on plotting both the positive and the negative relationships contained in a system, and, more importantly, on using the function analysis as a means of identifying the contradictions, ineffective, excessive and harmful relationships in and around a system. Function analysis thus becomes a very powerful problem definition tool.
3) Functionality is the common thread by which it becomes possible to share knowledge between widely differing industries. A motor car is a specific solution to the generic function 'move people', just as a washing powder is a specific solution to the generic function 'remove solid object'. By classifying and arranging knowledge by function, it becomes possible for manufacturers of washing powder to examine how other industries have achieved the same basic 'remove solid object' function. '*Solutions change, functions stay the same*' is a message forming a central thread in the TRIZ methodology: People want a hole not a drill.

The emphasis TRIZ places on functionality demands that engineers and scientists adopt a much more flexible approach to the way in which they look for solutions to problems. The age of the specialist is coming to an end; it is no longer sufficient for mechanical engineers to only look for mechanical solutions to their problems when someone from, say, the chemical sector may already have discovered a better way of achieving the function being sought – Figure 2. This is particularly important in the waste industry.

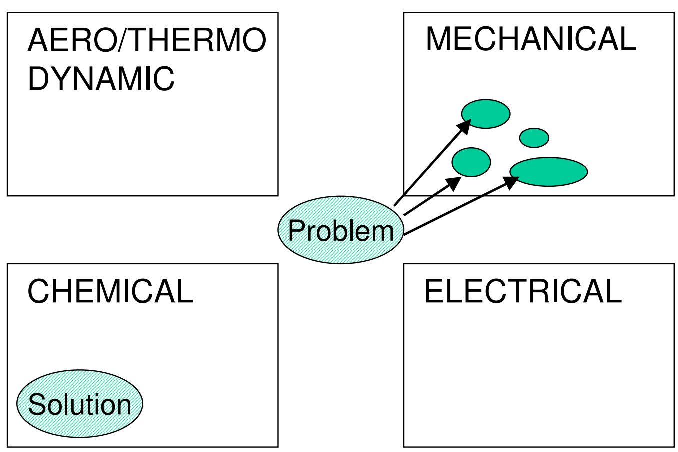

Figure 2: Solution Spaces

A number of functionally classified knowledge databases are now becoming commercially available on the Internet

Use Of Resources

While the previous three pillars of TRIZ could undoubtedly have been uncovered anywhere where the researchers showed the dedication shown by the TRIZ team, the 'resources' pillar is probably uniquely Russian. Resources relates to the unprecedented emphasis placed on the maximisation of use of everything contained within a system. In TRIZ terms, a resource is *anything in the system which is not being used to its maximum potential*. TRIZ demands an aggressive and seemingly relentless pursuit of things in (and around) a system which are not being used to their absolute maximum useful effect. Discovery of such resources then reveals opportunities through which the design of a system may be improved. In addition to this relentless pursuit of resources, TRIZ demands that the search for resources also take due account of negative as well as the traditionally positive resources in a system. Thus the pressures and forces we typically attempt to fight when we are designing systems, are actually resources. By way of an example of this 'turning lemons into lemonade' concept, Russian engineers often think of resonance as a resource. This is in direct contradiction to most Western practice, where resonance is commonly viewed as something to be avoided at all costs. TRIZ says that somewhere, somehow, resonance in a system can be used to beneficial effect. In effect, resonance is a potent force lever capable of amplifying small inputs into large outputs. Resonance is currently being used to generate beneficial effects in a number of new product developments from vacuum cleaners, paint stripping systems on ships (firing a pulsed jet of water – existing resource! – at the local resonant frequency of the hull), and in helping to empty trucks carrying powder-based substances more quickly.

CASE STUDY 1 – BIO-MASS COMBUSTION SYSTEMS

Disposal of a wide variety of organic materials - by-products of food manufacture and distribution (e.g., fryer oils; waste scraps; last-press edible oils such as canola and olive oils, food processing wastes, seafood industry wastes); by-products of paper and other wood industry manufacturing (e.g., cellulose and lignin by-products); yard waste such as leaves and grass clippings; rice hulls; bagasse; seaweed; milling waste; cotton waste; animal waste – are all expensive, time consuming, and generally require significant processing if they are to be considered for any useful downstream application. One such possible application is conversion for burning in power generation systems. The difficulties of economically extracting practically useable combustable fuel from biomass are well known.

The conversion from waste to fuel is an area full of contradictions. Contradictions considered here include those associated with the duration of time required for biodegradation processes versus the cost, use of energy and harmful side-effects of accelerating the process, and the desire to produce easy to burn bio-mass 'particles' versus the amount of energy and difficulty in breaking down bulk materials.

The Contradictions part of TRIZ seeks to guide problem solvers to means used by others facing similar contradictions in whatever industry. In the case of the contradiction between degradation time and amount of power required to accelerate, the Matrix gives a very clear steer towards the use of a) changes of state, and b) enriched atmospheres as strategies used by others. Taking these triggers as a lead, a search of the patent database soon revealed a 2001 patent using super-critical water (a readily available resource again) using exactly these strategies, and claiming to be able to transform "*a wide range of organic compounds and biomass sources, including cellulose, chitin, starches, lipids, proteins, lignin, and whole cells into a hydrocarbon mixture similar to a sweet crude petroleum, along with volatile alkane and alkene gases (C_2 to C_5)*" in a period of time measured in minutes (Figure 3). The expected cost advantages of such a system – in which process times are cut by orders of magnitude – are yet to be quantified, but all signs point to savings comparable to the time saved.

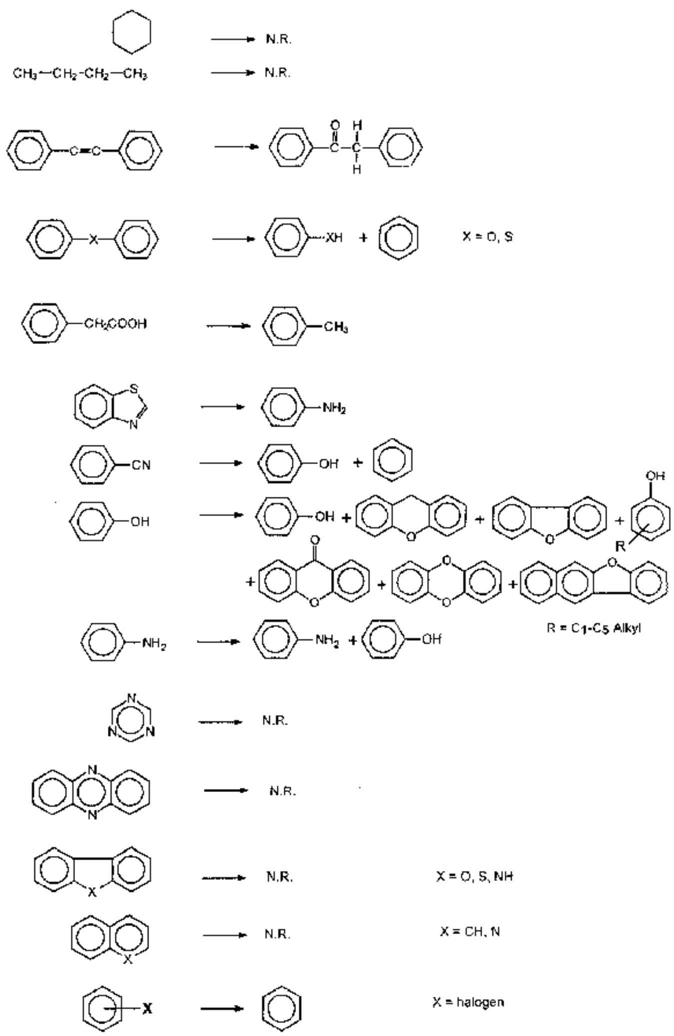

Figure 3: US Patent 6,180,845 – Transforming biomass to hydrocarbon mixtures in near-critical or supercritical water

With respect to the downstream contradictions associated with the desire to fragment the bio-mass into as small as possible a state during the combustion process – whether the fuel is in either a solid particulate or liquid state – the Matrix goes on to give a consistently strong pointer towards use of 'vibration' as a means by which others have solved similar problems. The consistency of this message from the Matrix was at first a little surprising (to this author at least) given that it does no look like an 'obvious' solution direction. Nevertheless, taking vibration as a lead it was possible to quickly identify the use of sonochemistry as a means of accelerating bio-degradation (8), and, more recently, as a means of breaking up fuel droplets into very small sizes in gas-turbine fuel injection systems. It is not clear that 'vibration' has been deployed in improving combustion of solid bio-mass (except in the sense of upstream sieving operations), and so there may be scope for generation of novel and effective solutions in this area. In terms of quantifiable benefit from equivalent use of 'vibration' – initial experience with gas-turbines employing a piezo-electric vibrator attached to the fuel injection nozzle suggested a 10 times reduction in minimum droplet size, which in turn is expected to deliver enormous emissions reduction benefits.

CASE STUDY 2 – THERMO-ELECTRIC POWER GENERATION

The problem of reliable power generation in remote areas served as a good example of the importance of functionally arranged knowledge for a recent Swedish project (9). The challenge was to find a cheap means of using existing resources in remote houses in northern Sweden – where the electricity supply is not always reliable. Under normal circumstances, the search for means to achieve the desired function would be restricted to the knowledge of those participating in the solution generation process. In this case, however, the problem solvers had access to a functionally-classified TRIZ knowledge-base. This database identified over 60 known ways of achieving the effect 'generate electrical field', one of which is a thermo-electric power generator (Figure 4) based on the Nernst-Ettingshausen Effect. As well as offering what turned out to be the most effective solution consistent with the constraints of the project, it is important to note that unless the author's had had the good fortune to know about the Effect, it is a solution option that would not have been open to them. As it happens, the reference reports a very successful prototype development programme in which the Effect was used to convert waste heat from the back of a wood burning oven into enough electricity to power the lighting for a house from an installation of around 12"x4"x4". The device looks set for widespread use in the near future.

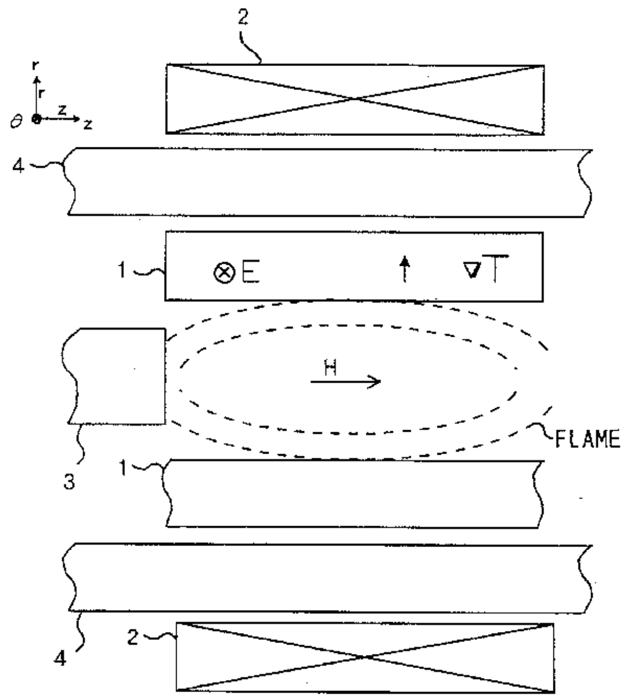

Figure 4: US Patent 5,563,368 – Thermoelectric Power Generating Device

One of the key elements of TRIZ is the recognition that if the system exists, it contains contradictions. Although effective in their current form, the performance of Nernst-Ettingshausen based waste-heat recovery generators could undoubtedly be improved by the elimination of current system contradictions. In this instance the TRIZ contradictions tools may well be able to speed the evolution of theses systems as well as to help generate significant new intellectual property. The above solution delivers a solution where one did not previously exist, and so the financial benefits are difficult to quantify. Even at a modest

20% efficiency, however, the device may be expected to deliver several million dollars per annum of electricity savings when deployed across Scandanavia, Canada and similar regions of the world.

’PROFIT FROM WASTE’ – APPLICATION OF TRIZ TRENDS

Lack of space dictates that not all of the technology trends uncovered by TRIZ researchers can be examined here. Instead, the paper interprets the ones most immediately relevant to ‘profit from waste’ scenarios:

Object Segmentation

The object segmentation trend (Figure 5) is applicable at many levels. At the micro scale, it suggests evolution directions for, for example, the evolution of combustion fuels (as seen in the biomass example above). At the macro scale it offers a pointer towards the importance of localized recycling systems. The segmentation trend here has distinct parallels with the steel, brewing, carpet-making and several other industries that have seen massive pay-off from moves from large, expensive and inflexible installations to small, dynamic and highly flexible mini-systems. In the waste industry – where profit appears to be difficult to engineer without considerable legislative support – it does appear to make sense on the (currently) small pockets of societies willing to pay a premium for ‘green principles’.

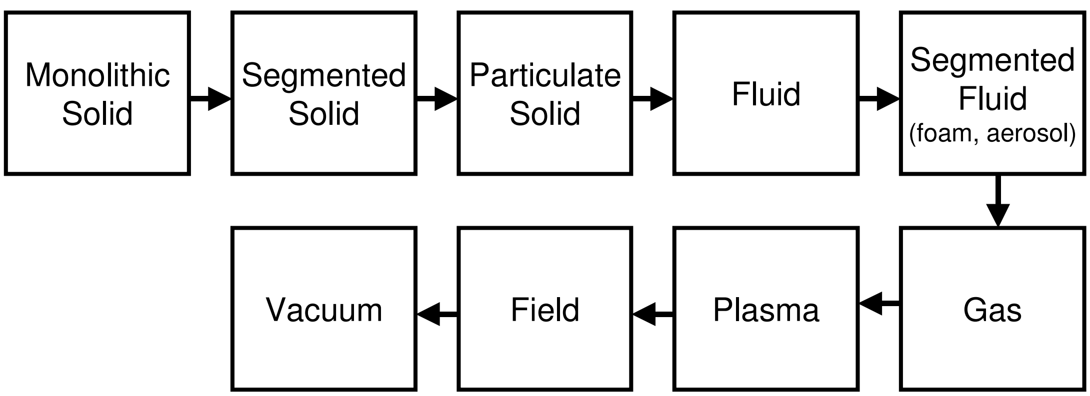

Figure 5: ‘Object Segmentation’ Trend

The trend has also been shown to be relevant to the emergence of small-scale turbo-generators for use in a growing range of applications. The global turbo-generator market is valued at around $4B. Coupled with CHP applications, the concept offers massive potential to ‘profit from waste’ sectors. Reference 10 describes the application of TRIZ to the design of turbo-generator systems at the component level, at the overall system level (examining reliability issues) and at the integrated super-system level – in which a fully integrated, self-sustaining district power, heating, sewage treatment and waste recycling system is projected.

Dynamization

The dynamization trend (Figure 6) describes the generic steps taken by systems as they evolve to increase their flexibility of use and operation. The trend denotes a historically endorsed evolution from mechanical to hydraulic/pneumatic to field based systems.

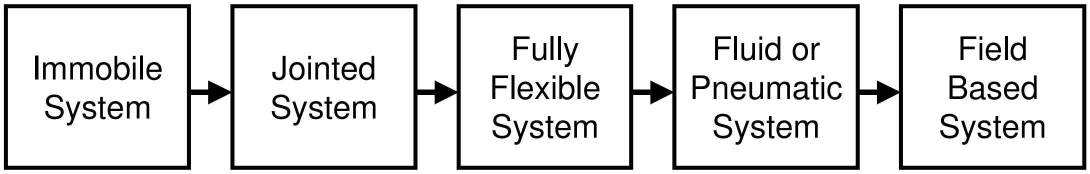

Figure 6: 'Dynamization' Trend

The trend can be seen in action in several waste industry technologies – from compost covers currently undergoing a shift from flexible sheets to spray-on fluid type coatings, to the design of bio-mass shredders, to the design of a wide range of energy transmission systems.

Mono-Bi-Poly

The Mono-Bi-Poly trend indicates the emergence of increased ideality through successive integration of different and/or systems. Again the trend has application at both micro and macro scales. We see the trend in operation at the micro scale in the construction of multi-layer compost covers in which each layer is required to perform a different useful function (i.e. insulate, air permeable, keeps out rain-water, isn't damaged by UV, protects against physical damage, etc). In a macro-scale business context, the trend has much in common with the 'co-opetition' (11) concept of 'complementors' – the search for synergistic opportunities for co-operation with outside organisations. This concept has particular relevance in the waste sector – where one persons waste is another person's useful resource. A good example comes from a May 2001 granted patent from a Japanese company, in which the waste from households and restaurants is combined with farm animal waste to the mutual benefit of all – Figure 7. Another multi-million dollar waste industry in the making.

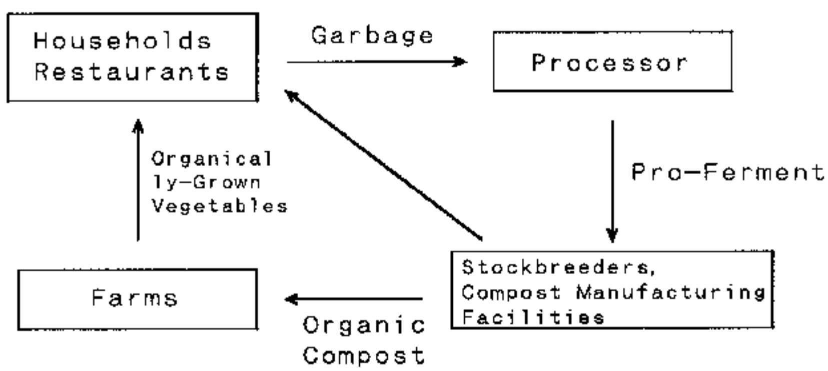

Figure 7: US Patent 6224771:Organic waste recycling method by Food Cycle Systems Co., Ltd.,

SUMMARY

1) The systematic innovation and creativity methodology, TRIZ, is formed around four main pillars, contradictions, ideality, functionality and use of resources, all of which have relevance in generating inventive and effective solutions to 'profit from waste' type problems.

2) TRIZ contains a broad spectrum of problem definition and problem solving tools. The paper has sought to demonstrate the application of some of these tools to a range of relevant problem types.
3) Viable profit from waste demands effective use of existing resources and the tackling of a number of important benefit versus cost and harm contradictions. TRIZ contains the most complete set of tools anywhere to assist in this process.
4) TRIZ research suggests that it is 99% likely that someone, somewhere has solved a problem similar to the ones you are currently facing. Access to external knowledge databases thus becomes a crucial initial point of focus during the design process.
5) TRIZ trends will not predict the timing of innovations, or of legislation that will drive evolution, but it does provide some very useful technology evolution trend data relevant to the waste industry. Among the likely key technology evolution trends are those towards increasing segmentation, increasing evolution to micro-scale consideration of systems, increased dynamization, increased system integration, and increased tendency towards human-less, self-supporting/self-sustaining systems.

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