A System Dynamics simulation model for sustainable value through the Viable Systems Approach

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ABSTRACT (max 400 words)

Purpose – Aim of this work is to shed light on sustainable value and develop a model, based on vSa and translated at applicative level through the system dynamics methodology, and through which it will be possible, once contextualized, to simulate the behaviours of business organizations interested in measuring sustainable value. According to the above-mentioned theoretical framework, value, traditionally considered as something objective and defined *a priori*, owns a multiple nature and is characterized by strongly subjective contents. This last concept means that the definition of value passes through the perspective of the subjects towards whom it is created (Recipient), in relation to the perspective of the entity who is interested in its creation and measurement (the governing body of the organizations). This conceptualization, based on vSa, assumes greater significance when we refer to sustainable value, which is the result of the concurrent consideration of three dimensions: economic, social and environmental. By adopting this perspective, value will be considered as a vector quantity and as the result of the subjective weighting of the different stakeholders that may change according to the considered organization.

Design/Methodology/approach – The paper will start from the analysis of the existing relations between the two considered approaches: system dynamics and vSa. Then, we will implement the theoretical framework in a simulation model trough system dynamics, which is capable to address systemic problems and is an expressive approach to solve issues rising in complex social, managerial, economic, or ecological systems: any dynamic systems characterized by interdependence, mutual interaction, information feedback, and circular causality. In order to translate theory into "action and application" we will develop a model through which it will be possible to exploit the advantages of vSa implemented into a simulation model.

Findings – The integration of the subjective perspective within a model for calculating sustainable value will consider vSa as the theoretical framework of reference and System Dynamics as the methodology that allows translating such approach into a simulation model.

Research limitations/implications (if applicable) –

Practical implications (if applicable) –

Originality/value – The reasons that have inspired this work derive from the consideration that, currently, there isn't a theoretical/practical approach to sustainable value measurement for business organizations that simultaneously considers the dimensions of the triple bottom line together with the subjective perspective of decision makers. From these considerations, derives the idea to integrate vSa and System Dynamics in analyzing the issue of sustainable value, whose triple dimension is usually (erroneously) seen in an optic that does not consider the interactions among those very same three dimensions.

Key words (max 5) viable systems approach, system dynamics, sustainable value

Paper type – Research paper

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1. Introduction

Aim of this work is to shed light on sustainable value and develop a model, based on the concepts developed within the Viable Systems Approach (vSa) and translated at applicative level through the system dynamics methodology.

The approach used here considers value as characterized by strongly subjective content; this means that it is not predictable and objectively determined. Rather, for its definition, it is necessary to identify the perspective of the subject to which it is created (recipient) in relation to the perspective of the subject that is concerned with its measurement (decision-maker). This assumption presumes that the concerned subject identifies his own specific context of reference and accordingly defines the measure of the value that he or she is interested in determining.

In this way, the concept of value is characterized by having a multiple dimension, because it involves a multiplicity of recipients and, consequently, the decision maker must include, among those involved by his government decisions, a set of subjects, with different expectations and different degrees of satisfaction. In this sense, value is intended as not exclusively targeted at categories of privileged subjects (generally, shareholders), but includes, in its determination and destination, different aspects and expectations that affect the system dynamics, thus requiring a wider perspective.

The reference here is to what Porter and Kramer define as "shared value" (2011), that is, the value created by the enterprise that is shared by the reference community of the individual enterprise and, within it, distributed and diffused.

This perspective is applied to sustainable value, that implies the integration of social and environmental instances within the dynamics of organizations, with specific reference to businesses. The need to consider these elements emerges from the efforts of International Organizations to set up methods, techniques and tools for evaluating companies that also include social and environmental elements. Such needs derive from the fact that the concept of value has assumed increasingly large and multidimensional characters, highlighting the need to consider, in its determination, categories of different subjects. The reasons that inspired this paper derive from the consideration that, currently, there isn't a theoretical/practical approach to sustainable value measurement for business organizations that considers, at the same time, the dimensions of the triple bottom line together with the subjective perspective of the decision makers.

Accordingly, the model that we will propose in this work is intended to respond to such instances. In fact, based on the vSa notion of Relevance, that is the importance attributed by the decision-maker to the other systems with which it interacts, the model allows to recover the subjective dimension of value by expanding the latter to the size of sustainability.

Starting from a review of the concept of value, we will refer to some of the main conceptualizations proposed by vSa. Further, these concepts will be the basis for the definition of a vSa-based System Dynamics (SD) model. Given the inherent capability of SD to grasp the intrinsic complexity of systems and the presence of articulated feedback loops, we decided to adopt such a methodology given also its circular nature in the process of learning and understanding, as well as of knowledge acquisition when dealing with a complex issue, like the one of sustainable value. Finally, we will propose an SD theoretical model for sustainable value based on vSa.

2. Value or values?

The processes of value co-creation, according to the S-D logic (Vargo, Lusch, 2008; 2011), suggest a change in roles and dimensions of relevance. At present, an important part of the process is played by customers, who are considered the key element from the earliest stages of the production process, and not only at the stage of final consumption. Customers are crucial for enriching the product, and are therefore considered essential for competitiveness. In this scenario, the process of value creation involves customers in a process of personal consumption, considering them as a real strategic leverage and as cocreators—thus suggesting that businesses may work primarily as supplements and managers of the resources that are needed and available, in order to generate a positive value spread between the concerned parties. From this point of view, the value proposition ultimately represents a specific package of benefits and solutions that a service system intends to offer and provide to others. The division of labor is at the root of many value propositions, which is why the modern meaning of service may be associated with a form of co-creation of value that involves both parties to an exchange (Prahalad, Ramanswamy; 2004; Vargo, Maglio, Akaka, 2008; Mele, Polese, 2011). It follows that:

1) Customers are not isolated, and the company-customer relationship is not only bilateral.
2) The result is the co-creation of value; what is created is an experience.
3) New elements for the value co-creation should be like a two-way dialogue.

Reflection n.1: No single actor can provide a complete cocreative experience by itself. The value is in the (personal) use but origins from a strong cooperation between parts as the base of the exchange.

Today, the objective of value creation, in fact, must be both internal (through the services and strategies for improvement of product quality, optimizing effectiveness, and efficiency) and external (as a function of relationships with other actors, looking for structural growth in terms of skills, knowledge, opportunities, techniques, and so on). There is, therefore, a close link between new considerations and the service system and modern interpretations of the value creation. Desiring to consolidate, and then synthesize, the representation of the levers of comparison between the studied paradigms, it is possible to assert that the new models of value creation must be implemented strictly in relation to the new concept of service, on account of the serious consequences for co-creation that the partnership of all the stakeholders in the process of generation inevitably brings (Wieland et al, 2012).

Accordingly, many scholars recently stated that the transactional competitiveness of the past, which was initially based on a competitive strategy, is now being replaced by adaptive behavior that is always characterized by systemic dynamic interactions (Barile et al, 2012a). From this, it can be checked to what extent consumers are not only interested in the goods or services as such, but rather in their representation of solutions to their needs. Consumers do not obtain the value directly from the product itself, but from its use, processing, or consumption, and by comparing it with other entities interested or involved in the build process (Katzan, 2008); the value of a product is thus derived from the benefit obtainable from the underlying service. The value is then derived from the process of coproduction, codesign, and comarketing, involving multiple contributions from different entities (including end users), thanks to the sharing of information, resources, skills, needs and risks. The value is therefore determined by the consumer at the time of purchase, through a personal "consumption" process favored by constant interaction with other parts of the service system in which it operates (Gronroos, 2008). This process helps to make the actual perceived value to that time only a potential value proposed. The customer then becomes a real cocreator of value and, consequently the firm is observed only as an integrator (and manager) of the resources necessary to the process of creation.

The processes of value creation are therefore strongly influenced by numerous aspects of the systemic view of a complex activity, and are oriented, focused, and deeply rooted in the new concept of service, knowingly or not (Polese, Carrubbo, 2008). Today, the management of a system must pass through a common ultimate goal (a sort of cognitive alignment) in an attempt to transform static relationships in dynamic interactions with other systemic entities and gain a mutual benefit in a specified context (as defined temporally and spatially).

Reflection n.2: The cognitive alignment fosters value-in-context; when resource integration is promptly finalized and system interactions qualify multi-part contribution in co-creation processes.

In an attempt to point out most of the qualification of a specific actor operating in the build process under study, it is necessary to dwell on the relationship that binds actors to other actors of the same service system, and with which they share an ultimate goal, resources, and information. Attempting to interpret these interesting conceptual intersections in systems, values, and service, we can notice

that value is in together and the co-creation processes are the right evidence of this for all kind of organizations (Carrubbo, 2013; Polese, Carrubbo, 2016). Indeed, the flow could be as follow: i) Value is considered to be an improvement in a system, as perceived by the system itself or by the ability of the system to be integrated in its environment; i)Value creation takes place as a potential resource has become an effective specific benefit; ii) Value co-creation has a win-win logic that considers the interaction among different entities represented by various service systems and by the desire to reach collective mutual satisfaction, in which the active contribution is multiple, the integration is maximum, and complementarity is fundamental; iii) Economic exchange is ultimately voluntary; it is the mutual use of resources for mutual value creation through two or more interacting systems; iv) The service systems are not defined by means of simple relations and interactions between resources alone: some resources must be active, and must thus ensure the proposal, agreement, and evaluation processes of value co-creation, which are often, if not always, of a network nature; v) The supply chain is reconceptualized as a network of service systems, and for this reason has a configuration that cannot be defined a priori, but rather is changeable; it can to adapt and evolve in relation to changing contextual conditions; vi) The contributions of knowledge, the application of skills, the ability to configure and reconfigure, and the desire to maintain relationships with long-terms subjects considered strategic all represent the elements of a systemic way of being adaptive; vii) Value is perceived and determined by the customer on the basis of value in use (through the previously defined consumption process); much more than something as defined *ex-post*, but achievable especially *ex-ante*, through the relevant contribution recipients in the value co-creation process; viii) The service can be seen as a final goal, rather than as a means in the process of value generation, as servitization, servicescape, service age, and service economy contribute to the consolidation of a true culture (based on the spirit of service that increases the value of action), rather than the ability to mediate towards something more specific and less generalizable.
The focus of value creation, and especially of value co-creation, must in this sense be examined both internally (through strategies of improving the quality of goods and services and through structural growth in terms of capabilities, knowledge, and opportunities), and externally (because of the collaborative relationships with other stakeholders). Nevertheless, the main reason why such good intentions only remain words is the difficulty to join necessities of a large number of actors involved in, each one owing different resources, possibilities and perspectives, that is – answering to a variety of subject with different priorities (as they could be on one side the need of citizen to live in a safe and healthy environment and, on the other side, entrepreneurial behaviours and attitudes that often do not respect such need).

Reflection n.3: Value is in together and the mutual benefit occur only when actors are able to accept and complement the perspective of the other part.

Indeed, to properly coordinate the coveted equilibrium at a systemic level, the strategic decision makers of any organization must understand how to share opportunities and resources among all the parts of the eco-system to ensure the satisfaction of each of them in terms of value. According to this logic, it is no longer essential to qualify the operators (Actors) involved, and the distinction between provider, operator or customer becomes almost irrelevant because the focus is on the business relationships, on the collaboration, and on the achievement of mutual satisfaction. It is needed to understand, concisely, that the relationships (of any kind) manifest their full potential value only if properly "grown" over time highlight the relevance of co-creation processes and to promote the win-win logic (Barile et al, 2012; Carrubbo et al, 2017) and, in this perspective, sustainability is the "instrument" that makes it possible to profitably keep the relationship in time (Hakansson, Snehota, 1995, 2002).
As recently pointed out, fitting helps to converge between demand and supply in a stated moment (t0) and consists of the actions made by the Supply side to interpret and manage the needs of the Demand side, modifying something in the initial value proposition; this up-grade produces even new levels (t0+1) in production/provision (Carrubbo et al, 2017). The decision maker has to choose, reminding

the effects on the St and the consequences descending, in terms of change in financial fluxes, in HR's management, in production processes, in the business policies as well. The evaluation/correction process usually followed is cyclic: i) assess; ii) design; iii) implement; iv) monitor; v) evaluate; vi) adjust; vii) re-assess. Each step can foster next one, by increasing in information, experience and knowledge of agents operating in the same value generation process, in which the multi-part contribution takes place and led to improvement in performances a higher level of quality proposed and perceived. Different effects come from fitting strategies and operations. In terms of value proposition, every provider must fit with evolving user's need, making adequate and coherent its solutions over time, especially in use (i.e. fitting process). As graphically represented below, the effective judge by final targets depends on the offer's capacity to adapt its own solution to the emerging changes, being to make the value proposition sustainable (Schein, 1990) and intending the value as the result of a personal perception of quality proposed and exchanged, while maintaining the appeal over time.

Reflection n.4: Sustainable value derives from right fitting solutions able to cover the distance between users' expectations (and satisfaction) and offer specialized capabilities (as distinctive resources).

The need to consider sustainability as a multidimensional phenomenon affecting economic, social and environmental aspects has led, in the last decades, several International Organizations to the need of building models that can measure it, according to objective and shared parameters that make reference to more or less large and articulated contexts. These models are based on a series of Indicators organized in turn in Indices that, on the one hand, can achieve comparable results in time and space by monitoring the nature and evolution of the phenomena associated with the indicators, on the other, they orient environmental policies by fostering the knowledge of the results obtained for users, as well as for "non-executives".

The goal of creating value, coupled with ethical and responsible imperatives, leads to the exclusion of a privileged prospect in an almost exclusive way (generally that of shareholders). Sustainability management, therefore, reconsiders the prospect of value in a broad and shared sense, underlining the priorities of the autonomous financial function considered to be those of the real government of society (Porter, Kramer, 2011; Sen, 1999).

The following are the main documents that companies voluntarily draw up, together with the balance sheet, and which cover the social, environmental and sustainability dimension in general. These documents leave to every actor the possibility of interpreting the contents, so that the single recipient has to recompose the individual "information fragments" that derive from a multiplicity of sources to a single, necessarily subjective, measure of the value created by the enterprise. The difficulty that arises in the single system, therefore, is to bring to the unity a measure of value which is, instead, totally multidimensional. Therefore, for businesses it will be necessary to have value measures that do not consider individual prospects (social balance, environmental balance), as opposed to a dynamic interaction of the same. This objective is also the basis of the elaborated model, whose methodological features will be outlined later.

In Tab 1. are reported the most common frameworks and tools for measuring sustainability at the organizational level.

Tab. 1 - Most common frameworks/tools for sustainable value at the organization level

Tool	Brief description	Dimension
Standards of accountability	by targeting business decision makers in the definition and formalization of the actions of government, concern the certification of ethical conduct by business organizations	Primarily social

Global Compact	sets out ten principles in four main areas (human rights, labor, environment and anti-corruption measures)	Social and environmental
Social Report	the certification of an ethical point of view that legitimizes the role of an organization as an economic entity that, in pursuing its own interests, should contribute to improving the quality of life of the members of the society in which it is inserted	Social
Environmental Report	contains different types of indicators for what concerns environmental management; environment in general; environmental performance; potential impact; environmental effect	Environmental
Sustainability Balanced Scorecard (Figge & al: 2002)	identifies the environmental and social issues that are strategically important for the business organization's business units of reference	Primarily social
Sustainable model (Figge & Hahn: 2004, 2005, 2006)	based on the concept of negative externalities, provides a measure of sustainable value calculated according to the environmental cost of the emissions of considered business organizations	Primarily environmental
Sustainability Report	drawn up according to the guidelines identified by the Global Reporting Initiative (GRI), consist of a set of indicators individually set for each dimension and in a set of guidelines for the reporting and compilation of financial sustainability	Economic, social, and environmental

Source: authors' elaboration

The main limitations of these approaches lie in their calculation of sustainable value in an exclusive efficiency optic, ignoring the dimension of effectiveness which, by definition, includes a wider (in number and nature) variety of subjects considered. These tools, in fact, do not consider the need of business organizations to move to more enriched formulations for the calculation and communication of their process of sustainable value creation, nor do they consider the call for the consideration of the subjective perspective that comes from both academic and professional world.

Starting from these considerations, it emerges the need of considering value with a wider perspective, that is multidimensional, dynamic, and vectorial, able, in essence, to include all the expectations of the different actors involved in the value co-creation (and distribution) processes.

3. The viable system as an information variety

In the light of the considerations carried out so far, in what follows we will define the theoretical assumptions on which to build a quantitative model of the main concepts of the viable systems approach (vSa) through the system dynamics modelling methodology; the original formulation will be then expanded to the elements that contemplate the dimensions of sustainable value.
vSa is a theoretical approach that starts from Beer's viable system model (Beer, 1972), according to which a system is viable if it "survives, remains united and is integral, is homeostatically balanced both internally and externally and possesses mechanisms and opportunities for growth and learning, development and adaptation, which allow it to become increasingly effective within its environment" (Beer, 1985).
Starting from Beer's conceptualizations, vSa proposes some advances that refers to the simultaneous observation of phenomena both from a structural perspective (static) and from a systemic perspective (dynamic) and defines viable the system that is also able to survive in its context of reference (Barile, 2009; Barile, Saviano, 2011). In this sense, survival is the ultimate purpose of the system and its ability to survive depends on its ability to establish relationships of harmony and positive interactions with the relevant entities present in its context (Golinelli, 2000, 2002, 2005; Barile, 2008, 2009).
Moreover, according to vSa, a viable system has a substantial equivalence (isomorphism) with an Information Variety, that can be defined as the 'knowledge patrimony' that it owns and can be defined by three dimensions: values categories, interpretation schemes and information units (Barile, 2009).
Information units are the most exterior level of the computer variety and express the "structural composition of knowledge" (Barile, 2009); they represent everything that can be *perceived* by the senses, or elaborated from the outside by the viable system, that is, from its specific context of reference. These data that come from the external, through elaborating processes, become information.
Interpretation schemes, then, are the intermediate level of the information variety, i.e. the "forms" of knowledge (Barile, 2009) that enable each viable system to rationally *organize information*. They represent the way information units are 'filtered' and transformed into information.
Value categories represent, for a system, its strong beliefs, the system of values that orientate it in the decision-making processes and from which they can not be excluded. They are, therefore, also the "resistance" that knowledge possesses opposed to change (Barile, 2009) and are responsible for the acceptance or refusal of messages, elaborations, etc, as they represent a subjective filter, and are the deepest level of the information variety.
Information variety can be represented as follows:

$$V_{inf}(k) = (U_{inf}, (k), S_{int}(k), C_{val}(k))$$

where:

$V_{inf}(k)$ = Information Variety of viable system K;
$U_{inf}, (k)$ = Information Units of the information variety of viable system K;
$S_{int}(k)$ = Interpretation Schemes of the information variety of viable system K;
$C_{val}(k)$ = Value categories of the information variety of viable system K;

We can identify the possible evolutionary paths of the Information Variety of a viable system, when interacting with one or more Information Variety/ies, with reference to the concepts of *Consonance* and *Resonance*. In fact, in this perspective, what matters is firstly the condition of the relationships and secondly that of the interactions, that vSa defines based on *consonance* and *resonance* (Barile,

2009). Consonance can be defined as the potential condition of compatibility and/or complementarity between interacting entities; resonance represents the consequent effects of harmonic interactions between two or more systemic entities and is related to pre-existent conditions of consonance (Barile, 2009). Consonance and resonance are the two drivers that orient viable systems' behaviors in their dynamics of knowledge and, as a consequence, in their behaviors.
As *Consonance* between two (or more) different Information Varieties defines the major or minor potential that the two (or more) Information Varieties have in aligning their knowledge, in terms of the Information Units used, we represent it as follows:

$$C_{ons} = \lim_{u1 \to u2} V_{inf1}-V_{inf2} / u_1-u_2 = \delta V_{inf}/\delta u$$

Resonance, instead, represents the change in the levels of Consonance and expresses the intensity with which it can grow or decrease with time. It can be represented as follows:

$$Res = \lim_{u1 \to u2} C_{ons1}-C_{ons2} / u_1-u_2 = \delta C_{ons}/\delta u$$

From the above, consonance can be defined as a line of action for the viable system, and involves the implementation/preservation of the conditions of harmony, correspondence, alignment and dialogue with the context of reference: it expresses the fundamental need of the system to match the values, cultures and needs of the surrounding society and to find recognition and consideration among the different entities that populate it (Golinelli, 2005).

Resonance, on the other hand, intervenes in the modification of consonance levels; in essence, it represents the way in which an information variety moves dynamically into the context in which it expresses its viability, and represents the level of sensitivity that it manifests towards the other systems with which it interacts with the perception of new information (Barile, 2009). Therefore, resonance, unlike consonance that may exist or not, also has a direction that qualifies, precisely, the evolution of consonance over time: it can be positive, as the change of consonance undergoes an increase over time, or negative, as the consonance undergoes a reduction.

4. Can System Dynamics constitute a viable quantitative manifestation for VSA?

Starting from the considerations laid out in the previous paragraph, in this section we will argue and try to demonstrate that System Dynamics can be a viable quantitative method to translate vSa concepts into a simulation model; thus, we will now start shaping the foundations of a system dynamics model based on vSa concepts, by analyzing the process of knowledge creation (Barile, 2009).

System Dynamics has its roots in Systems Thinking, it was developed in the late 50s by J. W. Forrester at MIT and was first described at length in Forrester's book *Industrial Dynamics* (Forrester JW, 1961) with some additional principles presented in later works (Forrester JW, 1969; Forrester 1971). It is a modelling and simulation methodology particularly fit at describing complex, non-linear, counter-intuitive feedback-driven behaviours, also characterized by feedback relationships and delays acting in the system. A central tenet of system dynamics is that the complex behaviors of organizational and social systems are the result of ongoing accumulations—of people, material or financial assets, information, or even biological or psychological states—and both balancing and reinforcing feedback mechanisms. The concepts of accumulation and feedback have been discussed in various forms for centuries (Richardson, 1991). System Dynamics (Sterman, 2000) is also a computer-based modeling method that makes use of formal models in order to understand the elements of complex systems over time. The main goal of System Dynamics is to understand how a system's behavior emerges and uses this understanding to gain insights on how policy changes in that system might alter its behavior. System dynamics uniquely offers the practical application of all these concepts in the form of computerized models in which alternative policies and scenarios can be tested in a systematic way that answers both “what if” and “why” (Tank-Nielsen, 1908; Morecroft J., 1985). Its main elements are *feedback loops* and *delays* that give rise to dynamic complexity, inherent in socio-economic systems and processes, through quantitative simulations (Sterman, 2000).

In other words, SD is a methodology for understanding, discussing and simulating complex systems over time (Sterman, 2000) and it has been widely used in many management, engineering, social and environmental application areas.

Some of the most important systems dynamics concepts are the following (Zock, 2004):

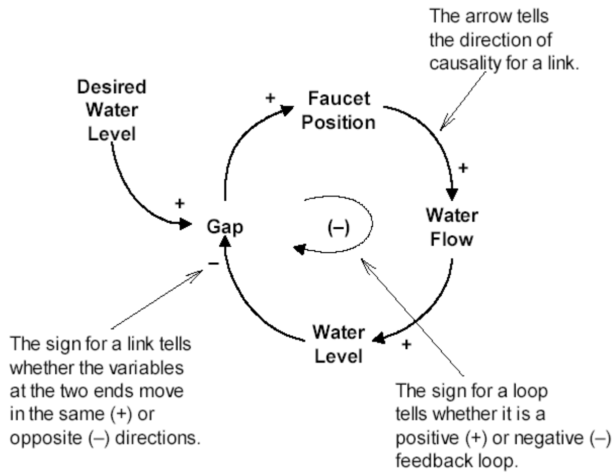
- **Stocks and Flows**: stocks (or levels) consist of accumulation within the systems while flows (or rates) are the transport of some content of one level to another.
- **Time delays**: as levels are changed only by the rates. The rates change is measured in a determined time interval.
- **Feedback loops**: a decision alters the state of the world, but at the same time indirectly influences itself, defines the situation we will face in the future, and triggers side effects and delayed reactions. Feedback loops can be positive or negative. Positive loops consist in reinforcing or amplifying what is happening in the system. Negative loops, instead, counteract and create balance and equilibrium.
- **Accumulation**: the levels, or stocks, are integrations. These are variables that cannot change instantaneously; they accumulate or integrate during time according the results of actions in the system.
- **Endogenous point of view**: it refers to the existence of a closed boundary which means the dynamic behaviour arises within the internal feedback loop structure of the system (Richardson, 1991).

In the system dynamics methodology, the structure of a system can be conceptualized through a Causal Loop Diagram (CLD), which is a map of the feedbacks present in the system. It is worth mentioning that such a structure can be classified according to the way feedback loops interact with each other, producing sometimes a few clearly recognizable structures, called system archetypes, that display a typical behaviour, which thus can be inferred (at least qualitatively) from the evidenced systemic structure of a system.

A system dynamics model consists of an interlocking set of differential and algebraic equations developed from a broad spectrum of relevant measured and experiential data. A completed model may contain scores or hundreds of such equations along with the appropriate numerical inputs. Modeling is an iterative process of scope selection, hypothesis generation, causal diagramming, quantification, reliability testing, and policy analysis. The refinement process continues until the model is able to satisfy requirements concerning its realism, robustness, flexibility, clarity, ability to reproduce historical patterns, and ability to generate useful insights. These numerous requirements help to ensure that a model is reliable and useful not only for studying the past, but also for exploring possible futures (Forrester, Senge, 1980; Homer, 1996)

The calibration of a system dynamics model’s numerical inputs—its initial values, constants, and functional relations—merits special mention. In system dynamics modeling, variables are not automatically excluded from consideration if recorded measurements on them are lacking. Most things in the world are not measured, including many that experience tells us are important. When subject matter experts agree that a factor may be important, it is included in the model, and then the best effort is made to quantify it, whether through (in approximately this order of preference) the use of recorded measurements, inference from related data, logic, educated guesswork, or adjustments needed to provide a better simulated fit to history (Homer, 1996; Graham, 1980). Uncertainties abound in model calibration, which is one of the reasons that sensitivity testing is critical. Sensitivity testing of a well-built system dynamics model typically reveals that its policy implications are unaffected by changes to most calibration uncertainties (Forrester, 1969; Forrester 1971). But even when some uncertainties are found to affect policy findings, modeling contributes by identifying the few key areas—out of the overwhelming number of possibilities—in which policymakers should focus their limited resources for metrics creation and measurement.

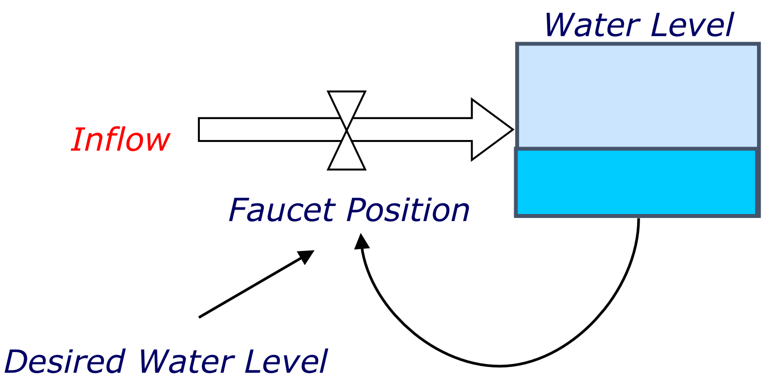
Figure 1: a causal-loop diagram (CLD) depicting a negative feedback-loop



Source: The Fifth Discipline, P. Senge (1990)

In SD, the system can also be analyzed through a simulation, which is possible after the construction of a Stock and Flows Diagram (SFD). A SFD is a quantitative assessment of the system. The Dynamics are pictured in the SFD and the model formulation is done by the elaboration of equations that expresses how the variables are interconnected with others and how the accumulation process is determined by the change in the flows altering the state of the system levels.

Figure 2: a diagram that translates (into Stocks & Flows notation- SFD) the CLD in Figure 1



Source: Authors' elaboration

To quantify the system, Stocks and Flows are used and the subsequent model is simulated with the use of computer software. A general representation of stocks and flows is illustrated in Figure 3:

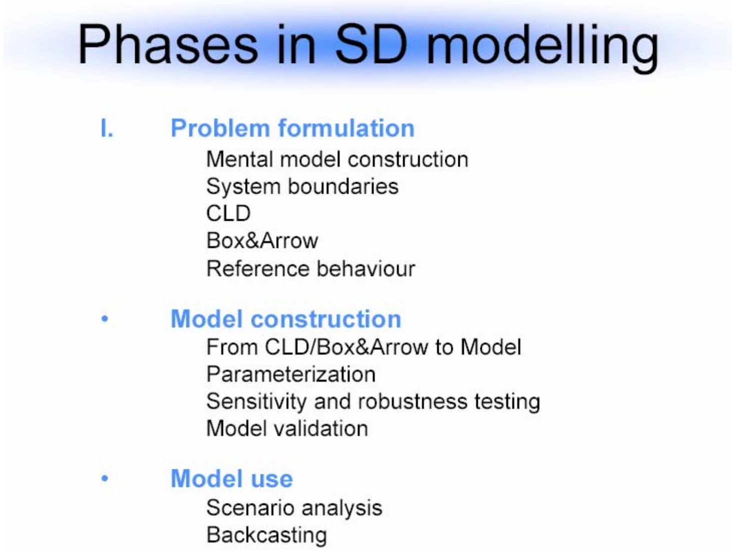
Figure 3: a stock accumulates the difference of its flows (input – output)

The structure above corresponds to the following differential equation:

$$\mathrm{Stock}(t) = \int (\mathrm{inflow}(t) - \mathrm{outflow}(t))dt + \mathrm{Stock}(t_0)$$

Building an SD model generally goes through a sequence of specific phases that can be summarized by the following Figure 4:

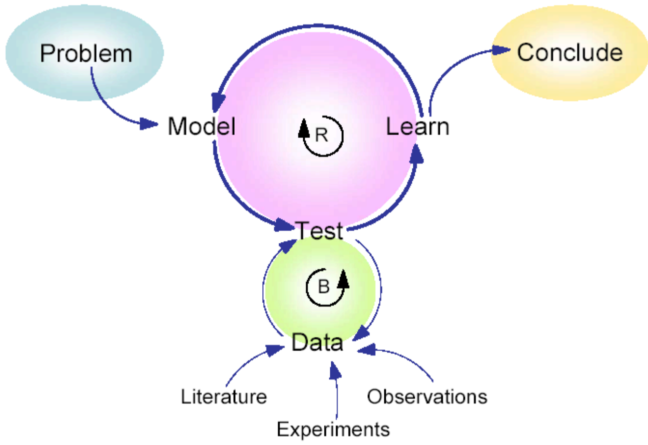
Figure 4: Phases in SD modelling



It is interesting to note that the process of building an SD model is inherently circular, both in its qualitative phase (the Systems Thinking one, where we basically build causal loop diagrams in order to understand the basic structure of the system under analysis) and in its quantitative one, as in fact, from each phase, one may want to go back to review the hypotheses that were built in previous phases.

As shown in the next figures, the learning curve goes through a well known process of "trial-error-refinement" (Fig. 5) where the refinement happens at the end of each cognitive cycle and after having learned how to modify the model in order to make it more similar to the reality (hence, to better shape the problem we attempt to solve).

Figure 5: a CLD describing the Learning process



System Dynamics models are normally constructed for further understanding a complex system, but they are often misunderstood for predictive models. However, the purpose of the method (and its main strength) is that it can capture underlying connections among system elements that cannot be easily perceived, it can identify and represent delays that affect the effectiveness of a policy and finally, it can remove the personal ideology and bias from the actual computations (Sterman, 2000).

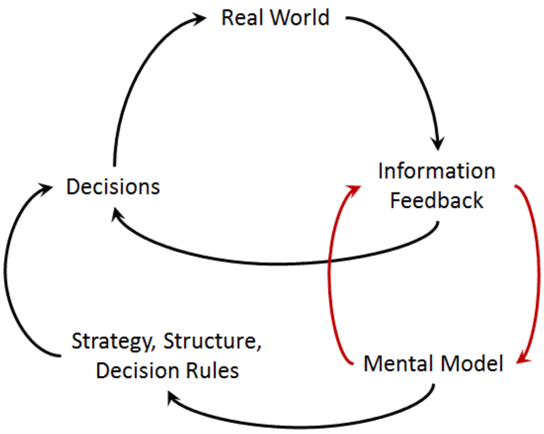
In other words, System Dynamics is a valuable quantitative approach to delve into understanding how a system works, what are its key/high-leverage points and how it can react to certain badly-designed policies by resisting change (just because the change effort was directed towards the points with the lowest capability to change) and thus present some counter-intuitive behaviours (which is a way to demonstrate how humans are characterized by bounded rationality, unable to manage too many "interdependencies" and correctly and coherently forecast the overall system behavior.

Armenia et al (2013) describe how issues such as those just depicted are key challenges for policy makers, which need effective tools to reduce uncertainty and understand the possible impacts of their policies, ensure long-term thinking, effectively manage crisis and the "unknown unknown", effectively communicate the reasons for certain decisions as well as their impacts (thus generate involvement), ultimately encouraging behavioural change and uptake through cooperation and systems thinking, ultimately creating not only a shared better knowledge but also providing the basis for a sort of social wisdom.

Given the above, as also reported in Armenia et al. (2015), the authors believe that the SD methodology can constitute an effective way to support building quantitative models that are described according to the vSa approach, also given the intrinsic systemic nature of the vSa approach itself and the inherent capability of SD to be able to model even the most complex and abstract concepts, nonetheless a framework which is born by the considerations that revolve around the concept of knowledge creation.

The model depicted in Figure 6, similarly to the one already commented and depicted in Figure 5, describes the way in which an individual takes decisions (acts), observes the results of his actions so to be able to control, at short-term, the outcomes by adapting decisions, and on a longer perspective, to adapt his mental models, hence even radically changing his basic assumptions, and thus implementing radical changes in his strategies.

Figure 6: source: Sterman's Business Dynamics (2000).-

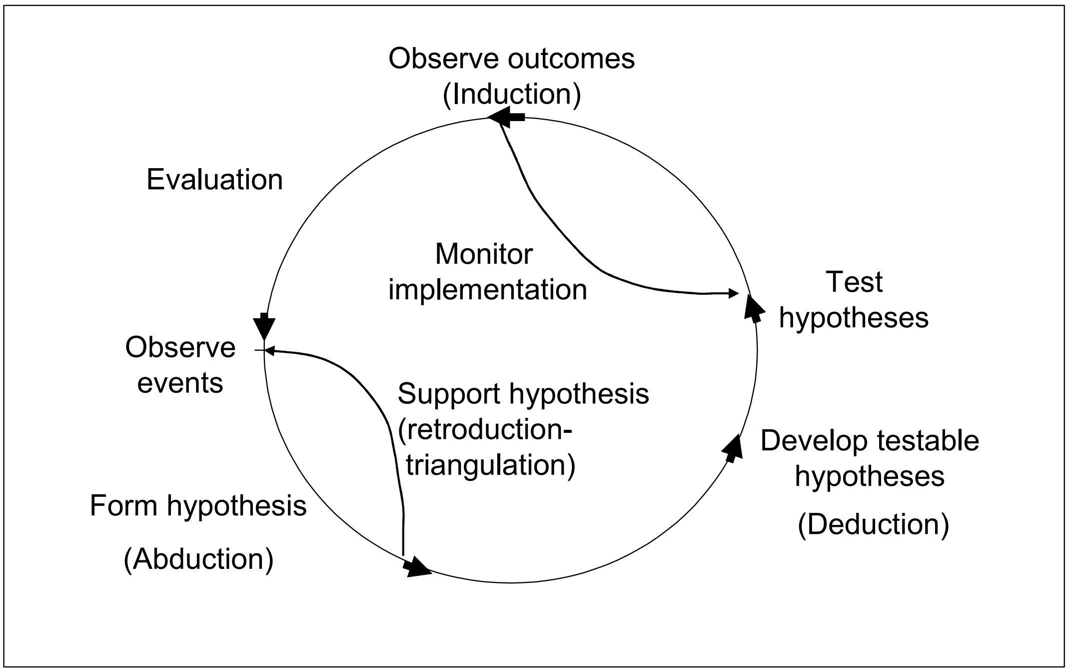


Source: Business Dynemics (Sterman, 2000)

5. Evidencing the Systemic Structure of the Learning Process

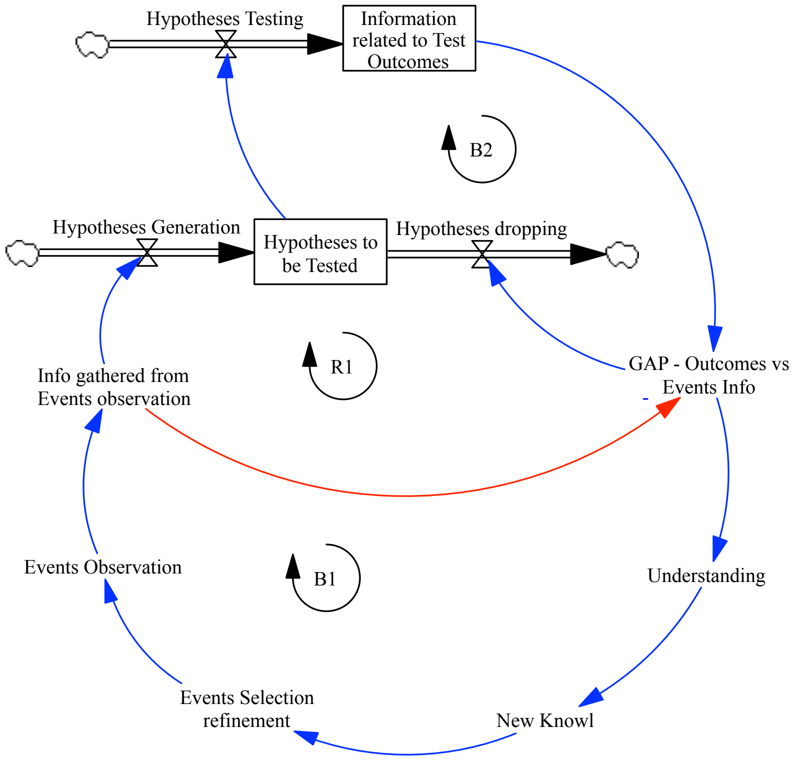
Understanding how a systems work is a key task in order to be able to act on those high leverage points that are capable of bringing to consistent and permanent change. A generalization of Sterman's learning structure (depicted in Fig. 6) can be found in the model formulation of Pierce's System of Inquiry, depicted in the next Figure 7, where events are observed, hypotheses formed and then developed so to be tested, and once tested, their outcomes are evaluated and matched to the originally observed events. In this main feedback process, there are two lower dominance control loops (one to support hypotheses formation and one to monitor tests implementation).

Figure 7: Peirce's System of Inquiry.-



In particular, we can develop the SFD of Pierce's System of Inquiry, which has been depicted, through the use of the Vensim ® software, in Figure 8.

Figure 8: Translation of Pierce's System of Inquiry into a first SFD.-

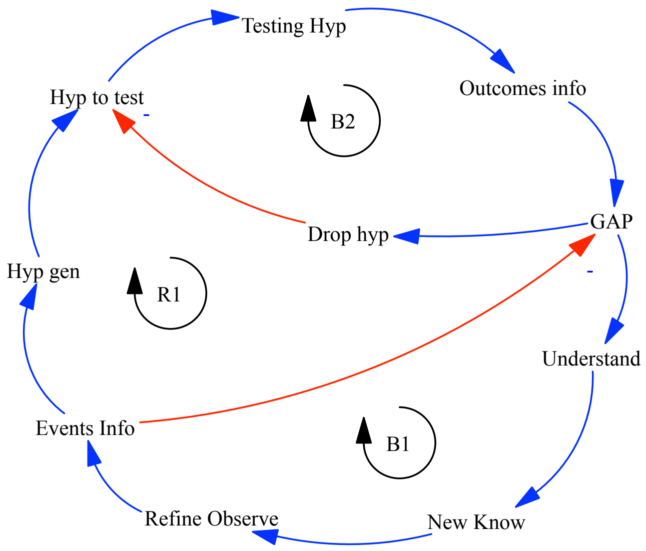


Source: Authors' elaboration

In other words, gathering information from observing events (i.e.: the system's behaviour), we usually generate hypotheses with reference to what might have given rise to them. Once these hypotheses are generated, they need to be tested in order to determine its validity. Testing such Hypotheses thus generate new information (related to the outcomes). This info get matched with the initial info that generated the hypotheses and the information gap is used on one hand to eventually drop any hypotheses which has been ascertained as non applicable (because they do not produce appreciating results) and on the other to generate a certain understanding about the system structure and the world around itself. Such an understanding bring to a new knowledge through which it is possible to perform an Events Selection 's refinement

The CLD of the qualitative model reported in Figure 7 has been depicted again through the use of the Vensim ® software and is reported in the following Figure 9:

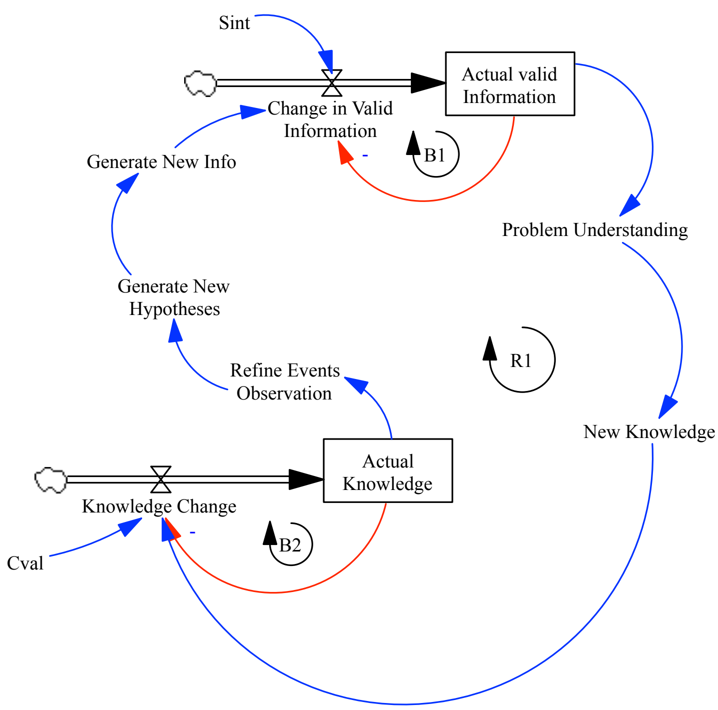
Figure 9: CLD of the model in Fig. 7.-



Source: Authors' elaboration

If we match Pierce's system of enquiry with the VSA process of new knowledge creation, knowledge alignment, capability to create new hypotheses on the problem to be solved and hence new information which in turn produces a new understanding and hence, again, new knowledge, we can easily redesign Pierce's derived CLD and SFD into the VSA SFD, that follows (Fig. 10):

Figure 10: an SD-description of the vSa-based model on knowledge .-



Source: author's elaboration

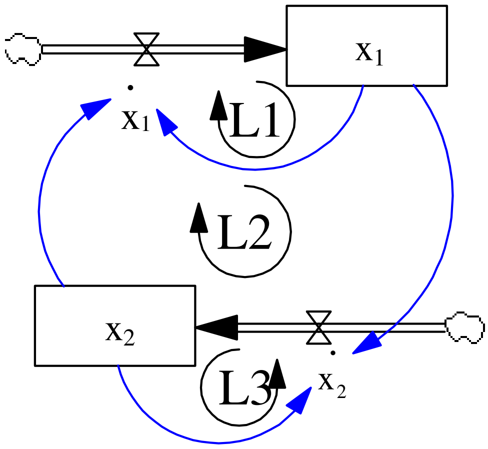
where:

- Actual Valid Information = Knowledge patrimony = **V_{inf}**
- Actual Knowledge = Knowledge alignment = **(dV_{inf} / du)** $= C_{ons}$

- Knowledge Change = Change in knowledge patrimony = **(dC_{ons} / du)** $= R_{es}$

This is a typical SD structure formed by one main, high-dominance, feedback loop with two lower dominance feedback loops, which can be matched against the following one:

Figure 11: generic SD-model describing a second-order system.-



Source: Guneralp

This is a well-known second-order feedback structure, displaying two stocks, each feeding the other one's flow.

The state-space representation of this system structure is the following:

$$\dot{x}_1(t) = a_{11} * x_1(t) + a_{12} * x_2(t)$$

$$\dot{x}_2(t) = a_{21} * x_1(t) + a_{22} * x_2(t)$$

with the following Matrix notation:

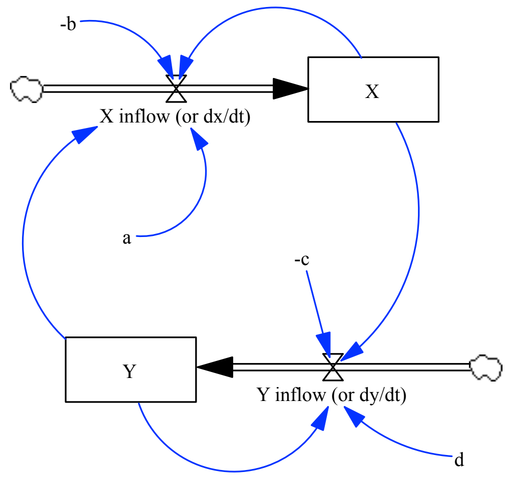
$$\dot{\mathbf{X}}(t) = \mathbf{AX}(t)$$

where the gain matrix A is:

$$\mathbf{A} = \begin{bmatrix} a_{11} & a_{12} \\ a_{21} & a_{22} \end{bmatrix}$$

This can be further generalized by the following structure:

Figure 12: further generalization of model in Fig. 11.-



Source: Authors' elaboration

Where:

$$\dot{x} = ay - bx$$
$$\dot{y} = -cx + dy$$

By simplifying the model (2 loops, d = 0 – that is the case for which there is no confrontation with previously available knowledge, rather the new knowledge gets just to integrate the old one in a process of continuous growth of knowledge – which is a reasonable assumption) we have the following :

$$\dot{x} = ay - bx$$
$$\dot{y} = -cx$$

$$\ddot{x} = a\dot{y} - b\dot{x} = \left(a\frac{\dot{y}}{\dot{x}} - b\right)\dot{x} = \left(-\frac{acx}{ay - bx} - b\right)\dot{x}$$

$$\ddot{x} = -acx - b\dot{x}$$

$$\ddot{x} + b\dot{x} + acx = 0$$

That is:

$$\boxed{a(d^2y/dx)(x) + b(dy/dx)(x) + c(x) = 0}$$

If we use the typical VSA concept to substitute for the constant a, b and c, we have the following:

- **a = C_{val}**
- **b = - S_{int}**
- **c = - K**

6. An application to sustainable value

6.1. A representation of sustainable value based on vSa

The elements outlined above are fundamental to understanding the competitive dynamics of viable systems and, consequently, their value creation processes and constitute a necessary premise for the development of the model presented herein.
However, the isomorphism between a viable system and an information variety requires further clarification, especially about the foundations of the model presented. In particular, by recalling the above-described information variety, it is necessary to identify the equivalent of the information resource, which constitutes an element necessary for the survival of the viable system.
The focus on value derives from the consideration that, beyond being one of the main business concepts, it has traditionally been defined as something objective and defined a priori; in this paper, instead, we consider it as characterized by a multidimensional nature and by strongly subjective contents. Starting from this, we further focus our attention on sustainable value, intended as the result of the concurrent consideration of three dimensions: economic, social and environmental.
By adopting the vSa perspective, we introduce a subjective weighting of the different actors that may change according to the considered organization, this means that sustainable value can be defined as the result of the composition of several values that, in turn, are the result of the composition of several 'subjectivities'.
By making a comparison between information variety and value, we will adapt the knowledge model proposed by vsa to the proposed subjective consideration of value (Barile, Calabrese, 2009; Barile et al. 2013; Iandolo, 2013; Armenia et al 2015).

In order to develop the model, we will make a comparison between what constitutes a resource for the knowledge process and what constitutes a resource for the value creation process in business organizations. Among all the measures considered, we believe that the one that most satisfies the above-mentioned characteristics is equity.

So we start from the following relationships (Iandolo, 2013; Armenia et al., 2015):

Information unit => (Productive) Resource
Information Variety => Equity

The identification of the correspondence/equivalence between the independent variable (information unit/ (productive) resource) and the dependent variable (information variety/equity), allows to redefine the concepts of Consonance and Resonance according to *resources* and *equity.* In this sense, Consonance can be defined as the variation in equity after a variation in resource, that is the *ability of a* resource *to influence* equity, and represented as follows:

$$\mathbf{C_{ons} = \frac{(E_2 - E_1)}{r_2 - r_1}}$$

where:
$\mathbf{E_2 - E_1}$= variation in equity
$\mathbf{r_2 - r_1}$= variation in (productive) resources

Resonance, then, can be defined as the *variation of* Consonance *in relation to the variation of the considered* resource and represented as follows:

$$\mathbf{Res = \underline{(C_{on2} - C_{on1})}}$$

$$\mathbf{r_2\text{-}r_1}$$

where:

$\mathbf{C_{ons2}\text{-}C_{ons1}}$= variation in Consonance
$\mathbf{r_2\text{-}r_1}$= variation in (productive) resources

In this sense, value can be defined as the change in equity that occurs according to the specific relevance of the actors present in the system's context of reference (Barile et al. 2013; Iandolo, 2013; Armenia et al., 2015):

$$\boldsymbol{Val_{Ssk} = Rel_{Ssk} * (E_2\text{-}E_1)}$$

Where:

$\boldsymbol{Val_{Ssk}}$ = Value;
$\boldsymbol{Rel_{Ssk}}$ = Relevance, that is the ability to affect the system's survival, strongly linked to subjective elements;
E= equity, intended as the composition of tangible and intangible elements that characterize a firm (equity, knowledge, trust, etc.).

The equation represents value *expressed as the variation of* equity *with a* subjective *weight*, given by *Relevance*, that can be defined as the 'importance' attributed to the specific system that has released the resource that has led to the change in equity. As an example, the value of extraordinary work, and the relative compensation for it, will be related to the relevance attributed to the system ($_{Ssk}$) "work". Therefore, in a market where labor supply is excessive the relevance of the work system is low; consequently, its assessment will be less than the value generated by the reverse case, where poor human resources give a high relevance to the work system. Relevance can be expressed as follows:

$$\mathbf{Rel_{Ssk} = Crit_{Sk} * Inf_{Sk}}$$

It is expressed as the composition of Criticality and Influence. Criticality is the 'structural' component of relevance, and can be objectively determined and is an important weighting factor. Influence is the 'systemic' component of relevance and depends on the effective ability of another system to influence a system's process or activity. Therefore, criticality is related to a relationship that is established with a subject and depends on the very nature of the resource concerned and the net relational benefits that will result from an exchange. Influence affects the entity with which the system establishes a relationship and depends on the level of constraints and rules present and the ability of control, feedback and intervention (Golinelli, 2011). Due to its systemic nature, Influence can be can be expressed as the variation of Consonance given the variation of the considered resource. So it can be approximated to Resonance:

$$\mathbf{Inf_{Sk} = \frac{(Con_2\text{-}Con_1)}{r_2\text{-}r_1} = Res_{Sk}}$$

Form the above, we can re-write the equation of value as follows:

$$\boldsymbol{Val_{ssk} = Crit_{Sk} * Res_{Ssk} * (E_2 - E_1)}$$

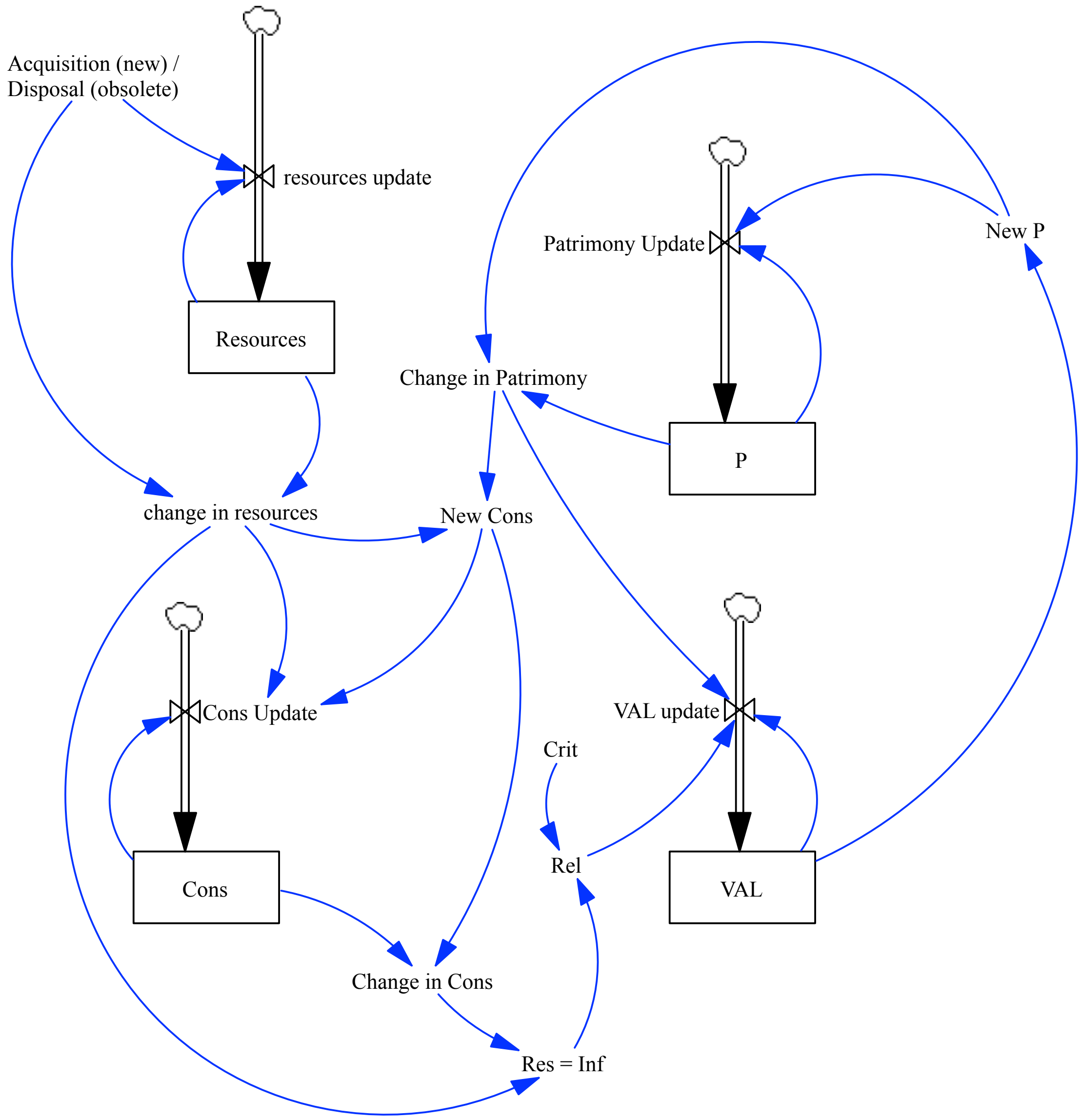
This equation expresses the value generated by the resource of the k-th system. Value is expressed in the perspective of the decision-maker and is, therefore, weighted on the basis of the relevance attributed to the k-th system. The objective measurability of the factor $\boldsymbol{Crit_{Sk}}$ could lead to hypothesis that the value attributed to the system is always the same, regardless of the decision-maker. However,

the consideration of the subjective factor ***Res*** $_{Ssk,}$ that is attributable to an explicit valuation prerogative of the decision-maker, introduces the character of subjectivity to the value attributed.
This means, in essence, that different decision makers, with the same accounting result in terms of equity, can reach totally different determinations of the dyadic value determined by the productive resource released by a specific system. This evidence suggests that the proposed criterion recovers a typical limitation of the more consolidated valuation systems that, although using third-party metrics to the enterprise, rely on the adoption of models that come to objective measures, or at least shared by a community of reference, of value, omitting entirely its subjective component.
In what follows, we will design an SD model for sustainable value based on vSa concepts.

6.2. Defining an SD model for sustainable value based on vSa

Given the definitions provided in the previous section of Consonance (variations of a company's Equity given a certain variation of its resources) and Resonance (variation of Consonance, with respect to a variation in resources), we can build a System Dynamics SFD where we have 4 main SFD structures that represent the updating of the new value of Resources, Consonance, Equity (or Patrimony) and Value. The new value gest confronted with the old one, so to determine the gap over which the calculation of Consonance and Resonance (with respect to a variation in Resources) and Value (with respect to a change in Equity and Influence - or Resonance) is carried out.

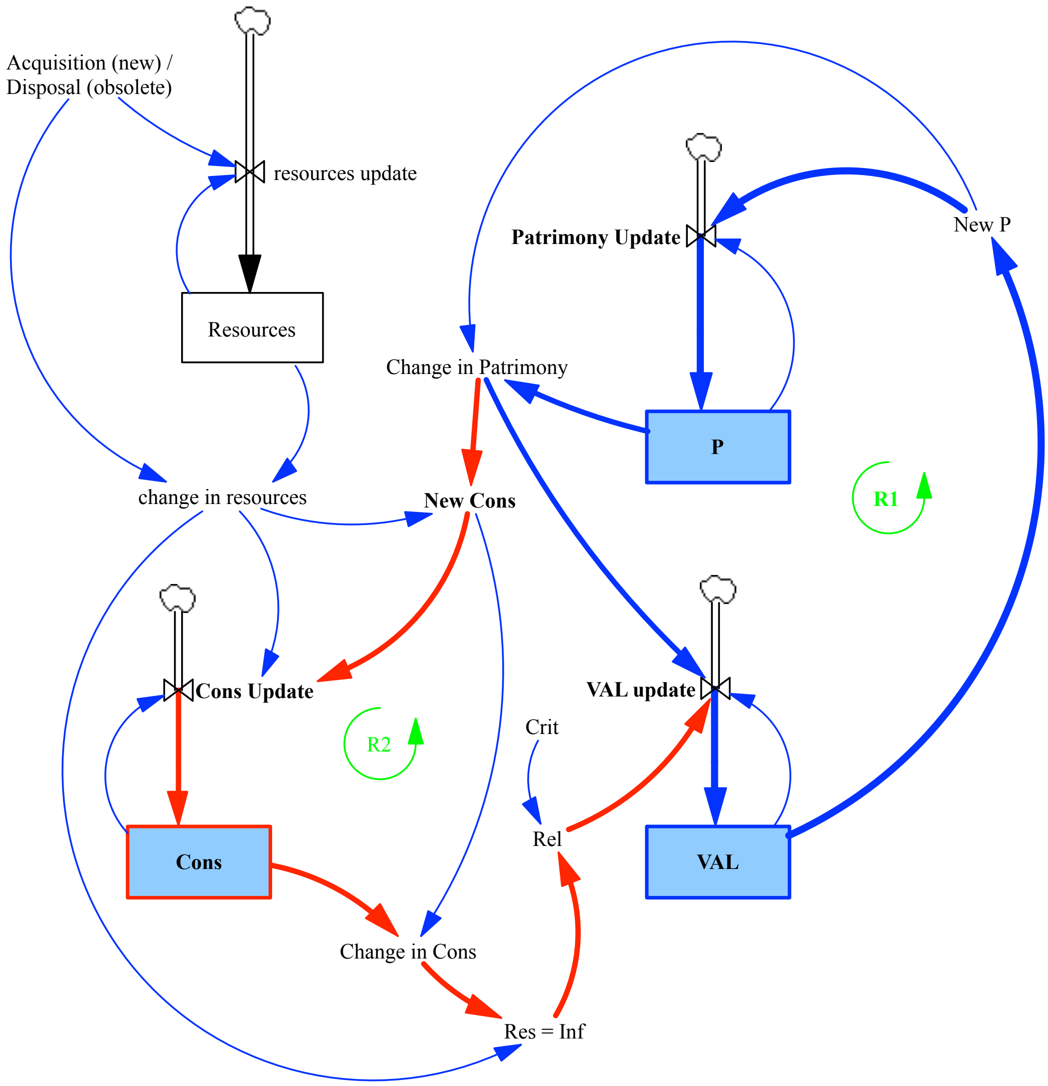
Figure 13: SFD model of Value Change.-



Source: Authors' elaboration

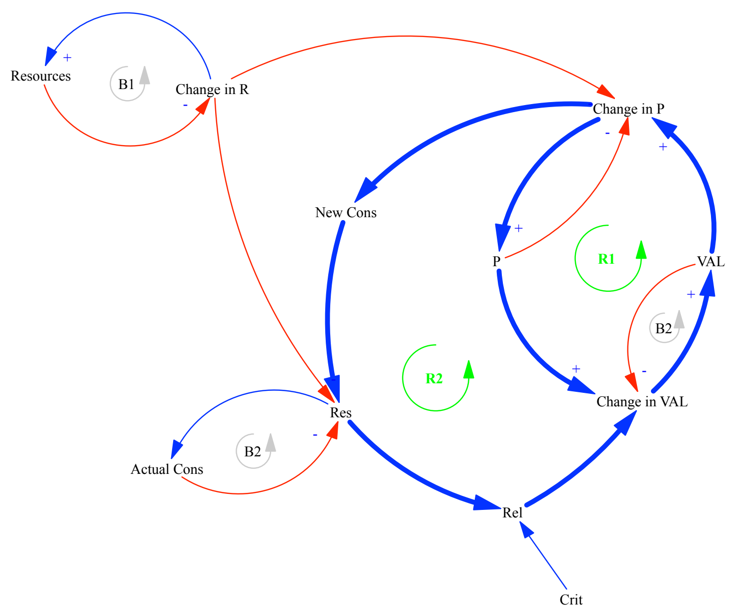
It is worth noticing that the structure just depicted displays, similarly to the structure designed in Fig. 10 (and following ones), a structure where we can identify two main feedback loops connecting three stocks (Figure 14 and Figure 15).

Figure 14: The proposed conceptual stock and flow diagram for value



Source: Authors' elaboration

Figure 15: The proposed conceptual stock and flow diagram for value -



Source: Authors' elaboration

This is a third-order system, which is described by a cubic relationship but depending on which variables we want to focus, we could also just consider two of them (i.e. Consonance, on the mixed-color loop's path) and Value (on the entirely blue loop's path).

7. Discussion and final remarks

The theoretical model outlined allows you to make a number of relevant considerations regarding its use in an enlarged perspective, which also consider the social and environmental instances that derive from the consideration of sustainability. The process of creating value as it emerges in this work is, in fact, the ability of the enterprise to meet, in different ways, the needs of the different systems that belong to the business context, which, in different ways, provide the resources the system needs for its activity. The goal of value is a long-term goal and is, therefore, tied to the choices and decisions of the decision-maker. The latter, as said, delimits the boundaries of action of the system dynamics when he defines subjectively the specific context within which the system itself will perform its dynamics. The concept of relevance, therefore, by recalling the characteristics of resonance, appears to be the central element of this new approach. It, in fact, contemplates, in its composition, a structural element, which is criticality, and one of a systemic nature, which is the influence. The different composition of these two forces leads to a measure of subjective value, as it faithfully reflects the decision-making paths and choices of the single decision maker.

Expanding to the three dimensions of sustainability, this model confirms its validity. In fact, it is possible to determine the value that each of the three dimensions concurs to create, inserting into the model just presented the traditional indicators used in the measure of each of the three areas. Each of the dimensions described is, in fact, one or a set of the other systems whose relevance can be calculated in terms of criticality and influence. The composition of the different instances from each of the three dimensions will allow to reach a measure of sustainable value, specifically constructed and determined with respect to the single system.

As previously stated, it is possible to outline the theoretical and applicative features of the model just presented. There is, however, the awareness that it may set limits on the definition of unique performance measures for individual systems.

Nonetheless, it is believed that it can be a good methodological and theoretical basis from which to reach a measure of sustainable value that, including the dimensions relevant for each single system, responds to the multi-dimensional instances and the prospects each approach to value should take into account.

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