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H. Inter – and Transdisciplinarity in Science and Technology

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Transdisciplinarity based on Category Theory

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Abstract. Physical reality can be characterized by the theory of categories that brings to the fore transdisciplinarity through invariants and structural and management patterns common to many fields. Applying the model of thinking the universe of systems according to category theory, many opportunities open for their modeling, but also for their planning, management and evaluation procedures. Structures and concepts in physical reality, as well as the relationships between them, become objects and morphisms through category theory, thus being valid in many fields. Objects can be aggregated through the relationships between them, in increasingly complex objects that meet the requirements of users in the knowledge society. In this respect, category theory provides the working tools for transdisciplinary modeling of systems on different levels of increasingly sophisticated reality.

Key words: transdisciplinarity, levels of reality, category theory, transport, logistics.

1. Introduction

In order to cope with the changes induced by the knowledge society, decision makers need strategic skills to develop the decision-making act in a transdisciplinary approach. As Basarab Nicolescu said, 'disciplinarity, multidisciplinarity, interdisciplinarity and transdisciplinarity are the four arrows of one and the same arc, of knowledge'. Transdisciplinarity is the higher degree of interpenetration and integration of several areas. It creates the possibility of generating new concepts and domains of knowledge by composing activities, processes and systems, resulting in patterns and configurations located at a higher reality level. For example, the composition of basic logistics systems (warehousing, forwarding, shipping, loading / unloading, transport, etc.) results in higher logistics entities (3PL, 4PL, corridor or logistic area, etc.). The logistic

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composition can continue repetitively from one level i to another higher (i + 1), reaching even the level of total logistics that we call *meta-logistics*. As philosopher Noica said, you put two unknown things face to face and you make a science out of two ignorances. The management logic of the new system can be decomposed into new entities that did not participate in the initial composition of the whole. Using the basic modes, one could build next successive levels, resulting in combined, bimodal, multimodal, intermodal, co-modal transports, as well as logistic chain and even logistic network, fig. 1.

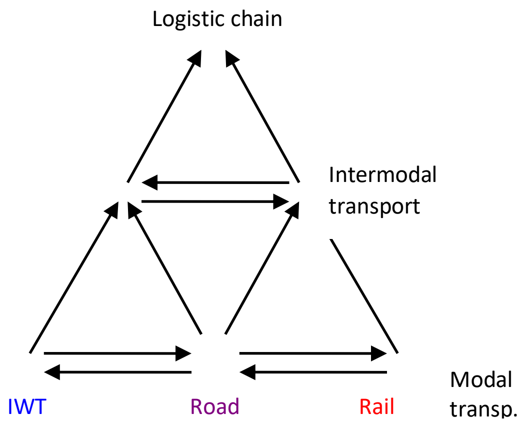

Fig. 1. Sequence of levels by composing systems.

2. Category theory, as transdisciplinary tool

Physical reality can be characterized by scientific theories and models, of which the category theory brings to the fore transdisciplinarity through invariants of structural and management patterns that are common to many fields [1]. Through them can be defined logistic objects still invisible, but which exist. The logistic triangle, making the connection between two objects of a reality level, can be considered an object composed of three objects-relations: production, distribution, consumption. Likewise, for the triangle of inter-, multi- or co-modal cooperation, three objects are needed so that each is the intermediary of the relationship between the other two, being on the same or on different levels [2].
The category is an algebraic structure different from the group in that the law of composition is not necessarily defined everywhere. The category theory represents the mathematical study of the algebras of functions, the abstraction of the idea of system of permutations of a set or symmetries of a geometric object. It is based on the idea of system of functions between certain objects. In category theory, an object $A \in \mathrm{Ob}(\mathbf{C})$ is not characterized as a set and does not care what elements it is made of, but is determined by its relationships with other objects $B \in \mathrm{Ob}(\mathbf{C})$. The most important are connections [4].

The logistic complex, made up of logistic systems or other simplexes, is moldable by homologous algebra in topology. As a topological space, a complex is determined by the set of its vertices and the specification of those that form simplexes. A topological space that is homeomorphic with a complex is called a polyhedron, and the homeomorphism will be called a triangulation: a decomposition of space into homeomorphic pieces with simplexes, pieces connected to each other. This suggests a model of the logistic network. Thinking in term of category theory is a systematization of reality based on the genus-species division and on the hierarchical definition of concepts from the supreme genera to the individual ones. If the model of thinking in term of category theory is applied in the logistic universe, many opportunities open to the modeling of logistic systems, but also for their planning, management and evaluation procedures.

3. Cooperation systems, as pullback

The fibrate product (pullback) M X_C N is the limit of a diagram consisting of two morphisms f: M → C and g: N → C with the same codomain. That is, it is a product that is restricted to certain objects [3], according to the diagram in fig. 2.
Categories M and N are two cooperating systems. For example, there may be transport modes: M = main mode of long distances (rail, iwt, sss), N = secondary mode of collection / distribution (road).
In a transport system serving a certain market C, combined transports consisting of transports (of containers, consignments of goods, shipments) performed by operators specifics to modes M and N are feasible. It result the couplings of the product
M X_C N over C.

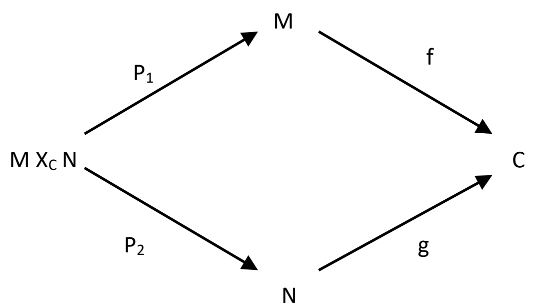

Fig. 2. Cooperation of two systems, as a pullback.

The fibrate product M X_C N generates the combined rail / road transport documents, defined over the transport demands in market C. The combined transport represents a superior level of reality to the level on which the transport modes are taken separately. The objects f (M) correspond to g (N) and are found in category C. The arrow P_1 is a functor which is a projection that tells how a certain main transport was served by the secondary collection / distribution transports. And the P_2 function shows how well a certain secondary service has been used. The diagram is commutative, $f \circ P_1 = g \circ P_2$, which is verified on the collection of combi elements in C. Other types of relations can be also identified, according to the diagram in fig. 3. The type of relations expressed by the projections P_1 and P_2 can be interpreted depending they are or not mono-, epi- or isomorphism.

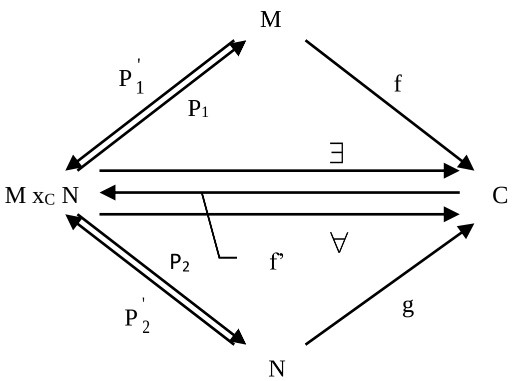

Fig. 3. Combined transport as pullback.

The characteristics of the P functors show the participation of M and N in the subproduct, i.e. their relationship. If P_1 is not an epimorphism, it follows that not all M participate in the product M X_C N.
The diagram contains other information by considering the dual projections (P'_1,P'_2), the existential and universal quantifiers (∃,∀), and the functor f' (the contract got by a certain operator).

4. A transdisciplinary model of a large system

In order to achieve a universal relation U over a certain transport system (local, national, European or intermodal, combined, bulk, etc.), a pullback is made for each existing relation in the respective system, after which, they are connected by pasting.
Conversely, the universal relation U can be decomposed into a relational scheme R with the instances I, realizing the detailing to the lower level of reality. These decompositions are projections of the entire product U into collections of by-products $R: \Pi (R_j) : U \rightarrow R$

An example of pasting of fibrate products is shown in fig. 4, in which K could be the logistic agents (shippers, forklifts, custom offices, etc.) that perform the combined transports based on modes M and N.

For example, by composing g o g' o P'_2, one can answer the question: who are the logistic agents through which road transport is carried out from combined transport.

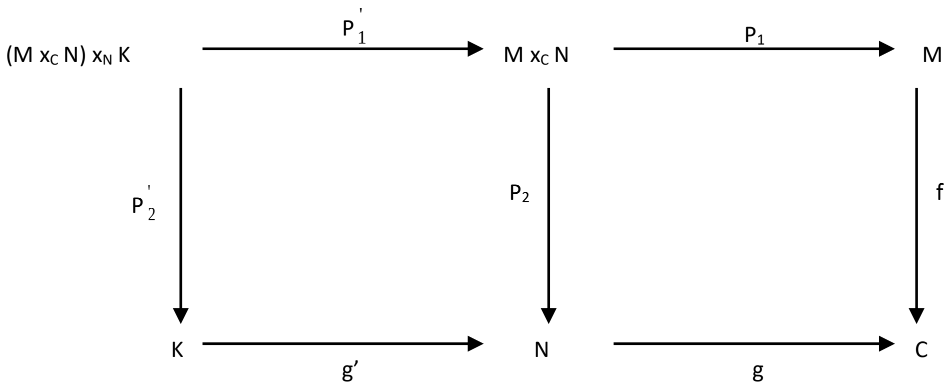

Fig.4. Intermodal logistics by pasting fibrate products.

A model with a higher degree of generalization can be constructed if, instead of considering the individual objects of categories M and N, we consider the concept of power-object (analogous to that of the power-set from set theory), i.e. we consider collections of objects of these categories.

A similar diagram is obtained in which, instead of each category M, N, C and (M X_C N), a corresponding power-object will be placed, and the arrows will be valid rules between the respective classes (clusters). Continuing, the general transdisciplinary model of the transport system results by replacing the classes in nodes with the component subsystems, i.e. a general pullback of the large system is obtained from the pasting of the components. For example, the European system composed of national systems, etc.

5. Composition of concurrently systems

The concept of institution [5] can be used to model a complex system as consisting of components working concurrently and coordinating its activities. A transport system or even a supply chain consists of a categorical diagram of models for each component. The logic applied to this system specifies the temporal and structural aspects of the component configurations. The diagram is formulated as an institution. The formulas are interpreted above the model diagram of the model components. Components are entities that can be composed to build other system, even a complex one.

6. Competition of systems at the level of objectives

The fibrate sum (pushout) $M +_C N$ is the colimit of a diagram consisting of two morphisms $f : C \rightarrow M$
and $g : C \rightarrow N$ with the same domain, fig. 5. The cooperation / competition of M and N systems provides examples to show the difference between pullback and its dual, pushout, in a certain C context, such as a certain goal, service market, etc. In the market for the transport of containers (or more generally, of intermodal units), each transport mode performs those services, transporting the containers generated in traffic by the economy of zone C, so that together, by the disjoint amount in the context of C, they give the traffic taken over by them: $M +_C N$.

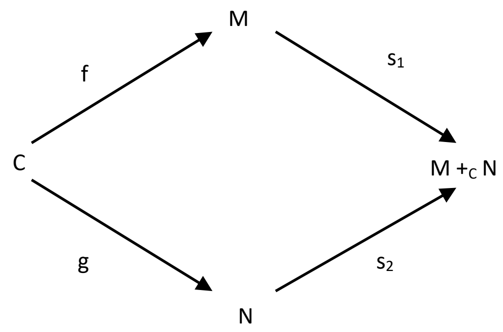

Fig. 5. Systems concurrently, as a pushout.

The colimita is in fact a breakdown of the two modal activities M and N. If the colimita is obtained by the participation of only some objects (ships, wagons, process, etc.) from M and N, the partial colimita results. The model can reflect the result of competition on the market of M and N systems, the agreements of mutual sharing or splitting the transport flows (cartel agreements, pools, etc.).
If the two systems interfere, contributing together to the realization of new services (combined transport, Ro-Ro, Ro-La, etc.), new information is generated, added value, linking M and N through the limit product M x N, which is represented by a pullback over C, fig. 2. The two modes create a new service in the context of C.

7. Systems modernisation

However, the use of models based on category theory also has a major disadvantage: knowledge of the system is closed in its own categories. That is why, for the revolutionary development of the system, it is necessary to break the categories, i.e. an intermediate chaos, followed by the construction of new categories (de-regulation and then re-regulation).

The alternative is the gradual, smooth evolution of the system, through the evolution of the respective categories, objects and morphisms, through natural transformations in slow dynamics, etc. In this case, there is the risk of returning to the *status quo ante*.

The change of economic paradigms, due to technical and technological progress, leads to the emergence of new concepts and transdisciplinary systems that require new types of indicators, consideration the productivity of the technological factor, new organizational and occupational forms. The technological factor, the role of substitution as a solution for economic growth, as well as a new sustainability based on digitization and technological, organizational and managerial innovation, are very important. In this sense, Solow's neo-classical model shows how increasing the saving rate, population growth and technological progress influence economic growth. Technological changes and the diffusion of technology through the network effect are endogenous variables that bring positive externalities, leading to increased yields of production factors.

8. Conclusion

The dynamic character of the logistic objects consists in the change of the connections between the objects, of the connection diagrams, of the structure of the objects, and the intensity of connections. Difficult problems modeled and solved in one area of activity can be translated into other areas located on equivalent level of reality, by using functors who move processes from one category to another. For example, the transfer of solutions between the EU and the Member States. The category theory models can specify some notions that were otherwise quite vague: universality, accessibility, inter-, multi-, inter- and trans-disciplinarity. It is performed systemic treatment, is modeled the relationship between part and whole, and the ratio analysis / synthesis (decomposition / composition).

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