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REVISITING THE QUESTION OF CENTRIPETAL AND CENTRIFUGAL FORCES IN URBAN SYSTEMS

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Abstract

The concept of centripetal and centrifugal forces was formally applied to the geographical sciences by Charles C. Colby in the 1930s; and for decades, these terms have been key elements used in explaining the development of cities and regions. Given that geographical research treats these concepts as represented by scientific metaphors, the work described in this article has sought to look critically at relevant issues from the physical point of view, i.e. in terms of Newtonian mechanics. Although the use of these metaphors is not always found to reflect the reality characterising the observed elements in the socio-economic system of a city and its surroundings, these may serve as an important element of explanations of 'classical' geography, new economic geography and Batty's concept of the "new science of cities", providing that certain objections are taken account of.

Key words

city-forming forces • centripetal forces • centrifugal forces • urban system • ontological approach

Introduction

A growing role for cities and urbanisation processes in the global socio-economic system is an undeniable fact, as is the complexity of the individual structures and connections that make up that system (Pacione 2009). This means that a steadily increasing role is assigned to explanations attempting to answer such fundamental questions as:

- In what circumstances are components of this system created, and when do these components disappear?
- What does their development and transformation entail?
- How can these systems be shaped to constitute relatively optimal conditions for human existence?

In searching for answers to these three very general, if crucial questions posed as part of the discourse on the functioning of cities, it is important for the background to the studied phenomena to be borne in mind constantly. One of the major attributes of an ontological approach to the explanation of socioeconomic reality is a mechanistic approach whose role

in urban and socio-economic geography has been growing for years now, mainly in association with reflections as to the role of centripetal and centrifugal forces in creating the reality that surrounds us.

The concept involving centripetal and centrifugal forces was applied broadly to the geographical sciences by Colby (1933). Although the terms had appeared before, they took their places as key elements explaining the development of cities and regions for decades to come thanks to Colby's article. Their mechanistic background has also found a prominent place among other physicalistic approaches, be these thermodynamic, gravitational or field-related. Also constituted in this way is an important alternative in the explanation-based-on-systems theory.

Overall, the concept of centripetal and centrifugal forces has accompanied anthropogeography since the end of the 19th century. With successive geographical approaches to presenting socio-economic reality, it has undergone a true evolution. Starting from foundations in anthropogeography based on the landscape and functionalist explanation, through the stage of theoretical concepts important for the geography of mature cities (1930-1970) and the founding of a new economic geography (end of the 20th century), to the recently evolving approach *The new science of Cities*. The durability of mechanistic-approach-explanations over such a long period undoubtedly attests to their rank and position in socioeconomic research.

However, despite significant scientific heritage and numerous conceptualisations, the issue of centripetal and centrifugal forces in urban geography requires further improvement, synthesis and clarification. Such objectives were therefore set for the work described in this article. An emphasis on the fundamental problem of defining centripetal and centrifugal forces has been equally important, and in many cases offers a *de facto* representation of the so-called 'double' scientific metaphor. The research question addressed in this article is therefore when, in geographical space, do we encounter centripetal and centrifugal forces, and when are we faced with other types of city-forming forces[1]?

The problem of the ambiguity of the two types of force under discussion is so important and timely that it may not only lead to epistemological disharmony, but also in some cases constitute an incorrect diagnostic base in real strategic and planning activities - unfortunately even at the level of national policy (e.g. Poland's *Concept of National Spatial Development 2030*[2]).

Explanations offered in this article refer to the ontological approach. The two discussed forces have been verified, and their specificity from the point of view of urban geography juxtaposed with their nature as defined within the framework of Newtonian mechanics. It has been assumed that such a combination will allow for a redefining of certain uses of the terms centripetal and centrifugal force. The article is therefore *stricte* explanatory, but also discursive in nature. A further part points to the frequently divergent points of view in terms of definitions of these forces, as well as their applicability in both the academic forum and planning or strategic policies (regional and municipal).

The problem of centrifugal and centripetal forces in research on urban settlement systems

The discussed issue of centripetal and centrifugal forces in urban settlement systems has already a very rich scientific output. This is undoubtedly due to the significance

[1] The term "city-forming forces" in this study encompasses the kinds of forces that play a key role in the process by which a town emerges in geographical space. It can also be defined in terms of genetic urban functions.

[2] The *Concept of National Spatial Development 2030* considers that development in Poland should be based on the gravity-diffusion model. Paradoxically, gravity forces are in this case identified with ... centrifugal forces. From the point of view of physics, the existence of such a system at all is impossible. Does it therefore gain verification as a metaphor with which to define the principles for the development and functioning of a state in spatial terms?

of the discussed issue in geographical and economic studies, as well as the fact that the first achievements in this area had already been made more than 125 years ago (Weber 1889). However, the development of research on these forces has undergone certain cyclical stages. Three out of four of these began with milestone publications. The cyclical nature reflected the fact that temporarily increased interest in the issue was followed by dissemination. For example, with respect to the second stage of conceptual evolution, Korcelli (1969: 22-23) writes: "The successors of C. Colby did not introduce anything new in later studies as for understanding the essence of the discussed forces, especially on the existing classification; and the issue of the impact of centripetal and centrifugal forces in metropolitan development became a truism in the 1960s".

As abovementioned, the research and conceptualisations of centrifugal and centripetal forces had 4 stages which were as follows:

- up to 1933, i.e. prior to the publication of the fundamental work of C. Colby in this area;
- from the 1930s through to the 1980s-1990s, when the dividing line was marked by explanations of the new economic geography that appeared, most especially those presented by P. Krugman;
- from the 1980s-1990s to the period after 2010, designated symbolically by the work of Batty (2013), who proposed the so-called "new science about cities";
- the contemporary period post-2013.

The two most important publications in the first period were works by Weber (1889) and Hasinger (1910). Weber's merit was to draw attention to forces he called locational. In his opinion, they point-fixed the so-called functional layers in geographic space. In turn, the essence of the explanations from Hasinger (1910) was a focus on the role centripetal and centrifugal forces play in shaping the settlement system as a being based on the concept of the city and the village. Hasinger's explanations generally came down to a formulation of a thesis that functions of cities are created as a result of centripetal forces, those of villages by centrifugal forces.

However, a turning point in the conceptualisation of centripetal and centrifugal forces as city-forming forces was reached with the fundamental work of Colby (1933), with its first reference to the ontological foundations of Newtonian mechanics as a background against which the socioeconomic development of an area, primarily in urban development, can be explained. Colby suggested that the mechanistic concept of centripetal and centrifugal forces be viewed as a set of socioeconomic forces experienced in real geographical space.

As has been noted, the post-World War II period brought a certain relativisation of these concepts, which were adopted as determinants, mainly in empirical and empirical-explanatory works. Philbrick (1957) had the impact of centripetal and centrifugal forces 'annexed' to explanations based on field physics. Their essence had a local dimension and constituted an explanation of the development of the city and its surroundings as being induced by gravity in the field of an urban centre. The 1950 work of Bogue as author of the "concept of metropolitan development" was later expanded on by Gottman (1961, 1978), with account primarily being taken of the role centripetal forces play in shaping cities and urban agglomerations.

New attempts and developments relating to centripetal and centrifugal forces in urban geography arose in the 1960s and 1970s. Gibbs (1963) proposed a concentration-deconcentration model based on two phases of development of cities and urban agglomerations (i.e. a 'stratigraphic' model); while Friedmann and Miller (1965 [1974]) proposed the *urban field concept,* one of whose foundations was, not merely the process or interaction of concentration and deconcentration, but also an equivalence between them, depending on the focus of attention of research on this development – in the spatial or temporal sense. From the other side, Hudson (1970) gave a brief description of the action of the centripetal and centrifugal forces, in relation

to time as well as space (the linear model). The strong functionalist context has been underlined by Henderson (1974) and Clark (1977).

A milestone in research on the role of centripetal and centrifugal forces in urban geography was reached with explanations from R. Lawton (Daniel & Hopkinson 1996; Krzysztofik 2014), who presented the action of centripetal and centrifugal forces on the non-inertial subsystem level, emphasizing the spatial structure of a city in particular.

Work done in Poland has also taken up the issues of mechanisms underpinning the development of cities and urban agglomerations, with the factor of the forces responsible for this development also taken account of. The most important studies in this area include: Malisz (1966), Korcelli (1969, 1974), Karłowicz (1978), Biderman (1978), Jędrzejczyk (1989) and Parysek (2011).

The third stage by which the issue of centripetal and centrifugal forces was conceptualised began in the 1980s and 1990s. In terms of time, it 'overlapped' with the second stage. In the third stage, the explanation of the forces' impact was largely based around assumptions in new economic geography (Barnes 2003). However, a breakthrough was provided in explanations advanced by Krugman (1995, 1997). It must be noted that the efforts to clarify this issue emerged in the early 1980s, in a work by Fujita and Ogawa (1982) devoted to external economies in business location. In this model, the forming role of centripetal forces is taken into account, along with mutual interactions of centripetal and centrifugal forces.

However, a real breakthrough came with a classification by Krugman (1995) highlighting the natural and socioeconomic attributes subject to the impact of city- and region-forming centripetal and centrifugal forces. In the "new economic geography", these forces, that are in the nature of genetic interactions simultaneously constitute, a background to fundamental questions about the nature of economic existence of humankind on Earth (Fujita et al. 2001). Through scientific discourse, these were referenced to seemingly conflicting issues, such as spatial concentration and spatial balance of economic activity, or spatial balance versus instability not caused by the concentration factor.

A further important aspect of the "new economic geography" entailed expansion of the field of research beyond the so-called circular causation exposed by Myrdal, and explaining that, in general, manufacturing is focused in areas with the largest market, albeit with the market being largest where industrial production is concentrated (Krugman 1993). A *novum* against these explanations, regardless of their nature and course, was to take into account as primary and genetic, forces that acted centripetally (the market) or centrifugally (manufacturing).

Nevertheless, the most important research reflection of the assumptions of the *new economic geography* is the firm statement that "it is the interactions between centripetal and centrifugal forces that shape the evolution of the structure of the spatial economy" (Fujita et al. 2001: 346). This thesis has also been confirmed by Soja (2000), who augmented it with an idea that these interactions should be seen on a number of different (spatial-hierarchical) scales, among which key interactions include: city centre–surroundings, one urban centre versus another of similar potential, and finally the relationship between centres placed in different locations on the hierarchical scale.

An interesting conclusion in studying urban development forces, making partial reference to the assumptions of the "new economic geography" has been proposed by Duranton and Puga (2000: 540): "The forces of agglomeration (centripetal) decide on the rational being of cities, while dispersion forces (centrifugal) determine their size". Unfortunately, any attempt to take reality into account tends to leave this thesis looking controversial. Both forces can determine the nature of cities, and their size.

The concept from Krugman has met with lively discussion, and criticism of some of the explanations presented (e.g. from Henderson 1995; Isserman 1995; Dymski 1996; Fujita & Thisse 2002; Olsen 2002). The criticism

has mainly focused on broader economic and spatial interactions, as well as issues of the functional typology of selected cities. It should be noted that Krugman's division of real geographical and economic attributes, acting on the basis of primary city-forming forces has been received favourably.

The fourth and (it should be stressed) potential next stage to the development of the way in which issues of centripetal and centrifugal forces are conceptualised relates to the proposal from Batty (2013), *The new science of Cities*. The essence of this proposed approach is to see the development of cities and regions from a mechanistic-thermodynamic point of view (in which the ontological point of view is also taken as a reference). *The new science of Cities* adopts key assumptions of "the new economic geography" in terms of the significance of centripetal and centrifugal forces (centralisation and decentralisation) in socio-economic and urban systems, with distinct augmentation by the thermodynamic aspect. There is no doubt that *The new science of Cities* combines the achievements of the physicalistic approach, the "new economic geography", and 'traditional' urban geography. This point of view has been advanced in Poland recently by Krzysztofik (2014), in his discussion of the ontological approach in explanations concerning the origins of the agglomeration of towns.

All of the socioeconomic studies presented have the common feature that centripetal and centrifugal forces are scientific metaphors well-defined both conceptually and methodologically. In almost all studies, including Colby's article and Krugman's work, there is not even a brief reference to the notion and essence of these forces, as considered from the point of view of classical mechanics. Of course, this lack is not a shortcoming. However, given the complex nature of the impact of these forces, the neglect as regards physicalistic reflection may give rise to some dissonance in interpretation. This thesis is confirmed by many of the proposed explanations. So, what is the true nature of the centripetal and centrifugal forces?

The essence of centripetal and centrifugal forces from the perspective of Newtonian mechanics

From the perspective of classical (Newtonian) mechanics, centrifugal and centripetal forces are apparent, which is to say that their interactions exist only from the point of view of a non-inertial system (a subsystem). The subsystem constitutes only a fragment of any arbitrarily defined 'complete' system. A subsystem, in this case, is a non-inertial system, whereas the system has an inertial character. In physical terms, centripetal and centrifugal forces interacting in a subsystem are therefore a consequence of the actions of other forces, which are primary ones like gravity or recoil force (Knudsen & Hjorth 2000). Primary forces act in an inertial system and lack the attribute of apparentness. A classic example of the two types of system and apparentness of interacting centripetal and centrifugal forces is a model showing different phases of vehicular movement. Each frame shows the inertial system – the vehicle and its surroundings, along with an observer and the non-inertial system (subsystem) limited only to the vehicle and its interior. What happens inside the vehicle therefore is (or may be) of an apparent nature. Existence is only manifested from the point of view of the inertial system. The upper right frame shows the phenomenon of the vehicle braking. An external observer interprets it as a result of the absolute impact of centripetal forces (braking, deceleration). However, a contrary situation applies inside the vehicle, where a person experiences the impact of centrifugal force (Fig.1).

The lower right frame presents the interaction system taking an opposite direction, from the point of view of both the observer and a person remaining in the vehicle. This time, these interactions result from the acceleration of the vehicle.

The essence of another feature of the impact of centripetal and centrifugal forces in physical systems is also presented in Figure 2. In this case, horizontal deflection of centripetal and

centrifugal forces' impact trajectories are presented. This is clearly an important attribute of the two discussed types of force, and one which differentiates them from gravity and the recoil force (Fig. 2).

The facts indicated are of fundamental importance, especially if we treat them as the basis for the construction of scientific metaphors; mainly in socioeconomic geography. The evident attribute of a scientific metaphor is that it does not have to include all the characteristics of the phenomenon or forms of existence to which it refers. However, by knowing all the attributes of an element to which we refer in a scientific metaphor, we can acknowledge that they do not agree with the reality described by the metaphor, or that there is another favourable element to which we can refer.

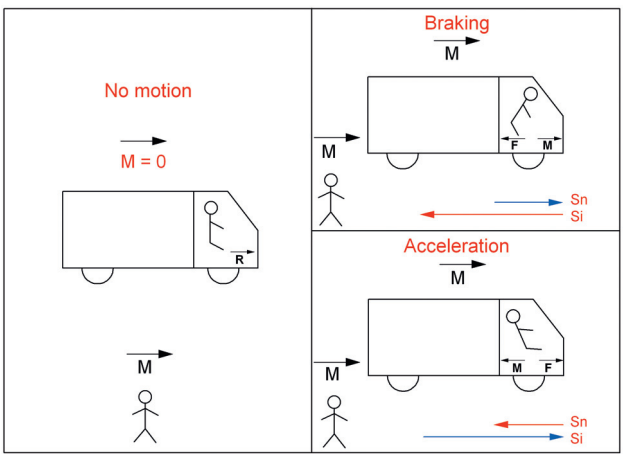

Figure 1. Activity of centripetal and centrifugal forces in the inertial and non-inertial (sub)systems
Symbols: M – direction of vehicle in motion; F – direction of force; Sn – phenomenon from the point of view of the non-inertial frame; Si – phenomenon from the inertial frame point of view.

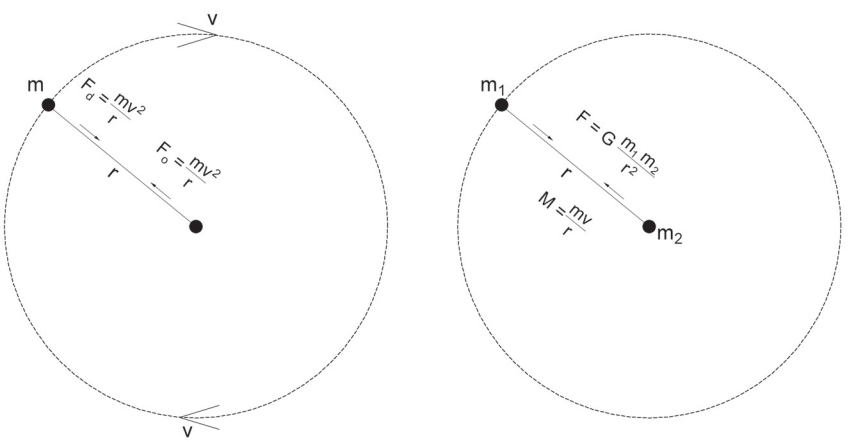

Figure 2. Model depiction of the action of centripetal and centrifugal forces from the point of view of mechanics
Symbols: F_d – centripetal force, F – centrifugal force, M, m, m_1, m_2 – mass, v^2 – acceleration, r – radius, v – speed of rotation.

Between a scientific metaphor and reality

The above dissonances of interpretation undoubtedly appear with comparative analysis of the above presented attributes of the impact of centripetal and centrifugal forces, as depicted by Newtonian mechanics and principles of applicability of the concepts of the centripetal and the centrifugal forces in socioeconomic geography. This dissonance raises such fundamental questions as:

- What are the centripetal and centrifugal forces in urban studies?
- Are development conditions we experience in an analysis of a specific region or city always related directly to the forces discussed?
- Which elements of geographical explanations relate to definitional assumptions interpreted in terms of the Newtonian mechanics?

Answers to such questions are not simple as many authors, when referring to the concepts in question, present them against a different background and in different contexts. The differences relate not only to such distant studies as those presented by C. Colby or P. Krugman, but also to those developed within one research sub-discipline (e.g. new economic geography).

Among the emerging epistemological dissonances, three evoke most doubts. In each case, the difficulty is raised by the fact that a type of impact in definitive physical systems differs from that in socioeconomic systems. These issues are included in the following questions:

Can two systems in classical mechanics be balanced by one anthropogeographic system?

Can the centripetal and centrifugal forces in anthropogeography be deflected horizontally?

Can radial zones be an effect of the impact of centripetal and centrifugal forces in anthropogeographical space?

In reference to the first question, there can be no doubt that the key problem in the study of centrifugal and centripetal forces in socioeconomic geography is that their effects are defined as systems and subsystems. More specifically, a city is often considered a closed system, as are its surroundings, in some cases. From the ontological point of view, this is a wrong assumption (Synowiecki 1969; Jędrzejczyk 1989; Luhmann 2012). A larger town, including its surroundings, is only a subsystem. A city's system is an area under its influence in geographical space, given that the city is in direct interaction with this space. The space perpetuates the existence of the city and provides for its possible development, whereas the surroundings of the city are only a fraction of the system. In many cases, the surroundings do not determine the city's existence at all; with it rather being the city that determines the existence of its surroundings (Scott 1982; Thrift 1996). The treatment of a city's subsystem as a system is particularly unclear in places where the city's existence is determined by its strong functional specialisation. Such a city exists, not because of the relatively good conditions created for its development, but because in geographical space as broadly conceived, there appeared a demand for specialized goods and (or) services offered by this city located in this particular place. In many cases, the place in which these goods and services are manufactured may differ from what we experience at the moment. From this point of view, the paradigm of a city's location is secondary to the economic and social network that allows the city to emerge and develop. This issue is well described by Andrews (1954), Parr (2002) or Pacione (2009). Even here, the question of apparentness in (sub)systems is raised. It should be understood as a potential instability or potential limited durability of functions' continuity, and the (economic or demographic) potential observed at a given moment. The durable element is the potential of a larger region, country or nowadays, the world, which is relatively less exposed to instability than the potential of a single specialized city.

In conclusion, a city does not constitute a system from the ontological point of view, but

is a dependent subsystem. It shows features of non-inertiality and apparentness, which, in the functionalist approach, translates into dependence on the potential achieved in an interaction with a larger territory, like the country or the world. This reality is depicted *via* the example of the observed vehicle presented previously. The vehicle may be braking, accelerating or in uniform motion. Only in the last case is there compatibility of the reality experienced from the point of view of the inertial system and the non-inertial (sub)system. The first two situations present the apparentness of the impact of centripetal and centrifugal forces.

Yet another fundamental thesis should be imposed here. Since only the city or its closest surroundings are a non-inertial (sub) system, only within it do we notice the impact of the centripetal and centrifugal forces that are defined in terms of Newtonian mechanics? If this is the case, the question arising is: what forces determine the existence of a socio-economic system? These will most definitely be the physical forces of gravity and recoil (compare Fig. 2). Hence, in a settlement system, the groups of typological city-forming forces that interact are:

- primary forces of gravity and recoil that are constant for the entire system,
- secondary centripetal and centrifugal forces that are limited to the city's subsystem.

Furthermore, in terms of direction, it is the gravity force that compensates for the centripetal force, the recoil for the centrifugal force. There is a high probability that this compensation was one of several key reasons for the scientific metaphor of 'centripetal forces' to include gravity conceptually, and for the scientific metaphor 'centrifugal forces' to entail the impact described in the mechanics as the recoil force.

The second of the aforementioned dissonances is the issue of a conceptual problem concerning the trajectory of the impact of centripetal and centrifugal forces. One of the features of these forces is the phenomenon of horizontal deflection around the model of the circle. The research question is therefore whether, in geographical reality, the space is shaped by the model, which is presented in Figure 2. In this model, the impact points are stabilized on the r axis, which is static. The movement arising as a direct result of the impact of these forces takes place around the circle. In socioeconomic analyses taking account of the impact of centripetal and centrifugal forces, the situation is the opposite. On the one hand, the movement (flows, interactions, relationships) between the two points is indicated. On the other, attention is paid to the evolution of geographical structure taking place at these points, which has resulted from the interactions, flows, etc. referred to. In this case, these points are stabilised in real geographical space by fixed and unchanging coordinates, contrary to the situation reflected by the physical model.

In conclusion, the essence of the impact of centrifugal and centripetal forces in the relation between the physical model and the geographical reality needs to be seen as inconsistent, with the impact vector and the trajectory of movement specifically having contrary attributes. However, the firmness of this opinion is mitigated by analyses conducted within the framework of the new economic geography. It is particularly visible in the "Three-Region Case" model (Fig. 3), as presented by Fujita, Krugman and Venables (2001). One of the attributes of this model highlights the capacity of existing interactions, on the economic level at least, to change trajectory in association with:

- the existence of real barriers in geographical space,
- the destabilizing role of the impacts of other places (cities) – the natural ability of places emitting matter, energy and city-forming information to absorb these secondarily, following a change of structural parameters.

The third dissonance, between physical and geographical models in the context of the impact of centripetal and centrifugal forces, represents a problem indicated in part above. It falls within the question posed earlier as to whether radiant zones are an effect of the impact of centripetal and centrifugal

forces in socioeconomic space? The question is especially valid in the context of the two most famous graphic models showing the direct effects of the impact of centripetal and centrifugal forces in a city subsystem, i.e. Colby model (1933) and Lawton model (Daniel & Hopkinson 1996), that indicate clearly a concentric, rather than a radial, direction to the development of a city and its closest surroundings (Figs. 4a and 4b).

The question of the concentricity and radiance of zones in geographical space is significant because trajectories for the impact of centripetal and centrifugal forces in the physical model are radial. This attribute should suggest the similar shaping of the geographical

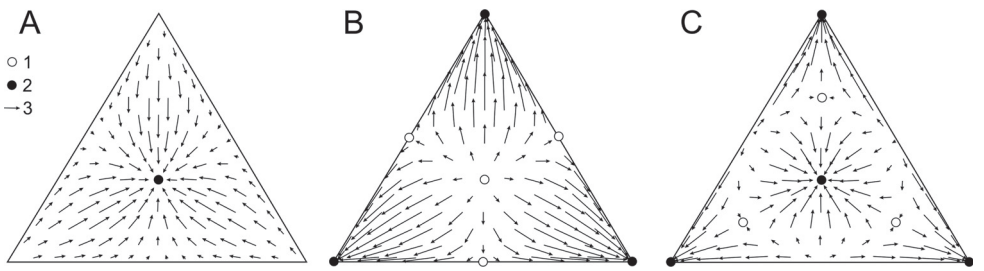

Figure 3. The "Three-Region Case" Model. Dynamics of vectors
Symbols: 1 – dominant centres in regional development where the determinant is low transport costs, 2 – dominant centres in regional development where the determinant is high transport costs, 3 – vectors of activity in the typical vector field.
Source: based on Fujita et al. 2001: 80-81.

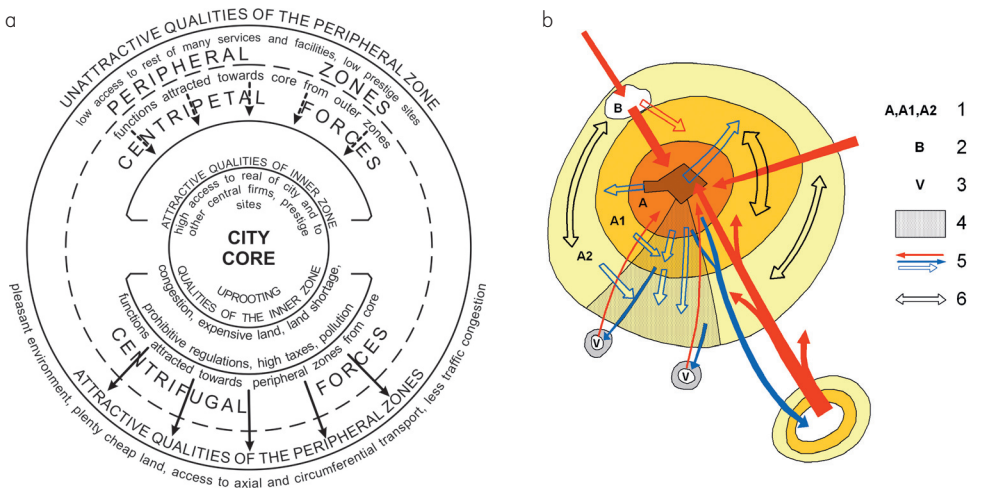

Figure 4a. Centripetal and centrifugal forces as basic elements impacting on the city. An original redraw
Source: based on Colby, 1933.

Figure 4b. R. Lawton's model of urban development in the nineteenth century
Symbols: 1 – stages in the concentric growth of the city, 2 – small town that has been engulfed by the spread of a larger settlement, 3 – developing suburban villages and centres, 4 – a middle-class sector, 5 – the action of centripetal and centrifugal forces resulting from movement/ motion: people, goods and some social-economic linkages, 6 – intra-urban movements.
Source: based on Daniel & Hopkinson, 1996: 137.

dimension to reality, but it is known that this is not always the case, with the concentric models in fact being closer to reality. The resulting cognitive dissonance therefore reinforces the belief that if the geographical reality disagrees with the mechanistic model, that model is perhaps inappropriate for its description on an ontological level. This thesis has not been truly justified either. Geographical reality is not merely an effect of the impact of the determinants stimulated by the city-forming forces discussed herein (Prigogine & Stengers 1997; Pulselli & Tiezzi 2009; Krzysztofik 2014), but rather is also affected by elements described by definitions of thermodynamics i.e. the flow of matter and energy, a system's entropy and negentropy, diffusion or, finally, the phenomenon of dissipation in space (Domański 2001). In real geographical space, these attributes have the ability to defragment or disperse existing structures, to homogenise structures, to create zone systems, and to create primary and secondary potential clusters.

Thus centripetal and centrifugal forces, together with gravity and recoil, co-create the material, energy and information reality in the geographical space at the elementary level. An important determinant of growth in the role of thermodynamic attributes also needing to be emphasised is the weakening potential for exerting an impact that characterises the forces discussed. This is weakening results from both the distance between two points remaining in the interaction and the potential barriers or 'filters' located between them. Figure 5 presents the initial deviation phase to the trajectories showing interacting city-forming forces. The differentiation of geographical (here socioeconomic) space reflects deviation of the trajectory characterising interacting forces, but also the direct impact of thermodynamic attributes.

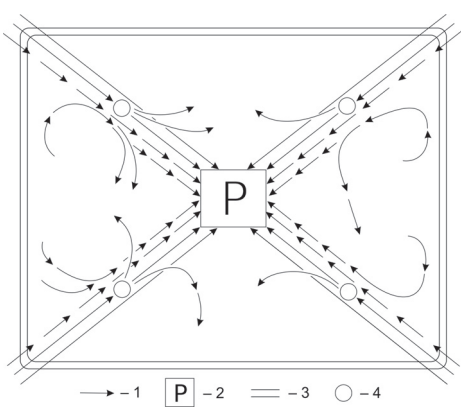

Figure 5. Activity of the city-forming centripetal forces in the settlement subsystem
Symbols: 1 – directions in which city-forming forces act within the subsystem, 2 – the city-forming point, 3 – limits of the subsystem, 4 – secondary (urbanised) centres participating in subsystem interactions conditioned by city-forming forces.

Discussion and conclusions

The interpretation problems presented in the previous section with regard to centripetal and centrifugal forces in socioeconomic space do not constitute a comprehensive list, though are ones that may be deemed essential, in the author's opinion. However, doubts and inconsistencies arising as the concept involving centripetal and centrifugal forces is used as a metaphor for scientific geographical research (as indicated in the previous section) do not in any way disqualify these from the general discourse on socio-economic organisation in space. Their nature inclines one to consider the actual role of city-forming centripetal and centrifugal forces in the genesis and development of settlement systems.

It should first be noted how the definitional scope of the concept entailing centripetal and centrifugal forces is also transferred onto *de facto* interactions involving gravity and recoil. This means that, in the context of geographical research, these describe both the interactions typical for centripetal and centrifugal forces and those characterising gravity and recoil. Of the latter two, only the concept of gravity is occasionally invoked at present. The concept involving the metaphor of recoil force is not used in the geographic sciences at all. Many analyses thus *de facto* employ a 'dual' scientific metaphor. In this case, geographical reality is described as a physical model. In epistemological terms, this is probably a significant

dissonance. In practice, we merely give a new integrative name to certain types of broader, socio-economic interaction. However, as we do this, we need to remember that not all 'centripetal' and 'centrifugal' forces have their physical features, and that this is a knowledge especially applicable to urban studies, economic studies, spatial planning and landscape research. An interpretation of the geographical reality that fails to recognise the specific nature of impacting forces at the inertial and non-inertial levels will lead to a false diagnosis.

For a long period, geographical research attempted to bypass the ambiguity described above by using forces of concentration and deconcentration as an analogy for centripetal and centrifugal forces. Concentration forces are directed inwards, towards a place capable of concentrating matter and energy, whereas forces of deconcentration are those that disperse city-forming matter and energy in geographical space. There is evident truth in this, as long as the phenomena are considered in the context of impact, rather than the final outcome, with cities developing and growing as a result of interactions between both centripetal ('concentrating') forces and centrifugal ('deconcentrating') ones. This reflects the fact that phenomena associated with the so-called centrifugal forces in fact form through interactions of the force involving recoil, whose attributes are non-unidirectionality, temporal limitation, and limitation by existing potential, as regards concentrated matter and energy, as well as accumulation in an area where the phenomenon occurs. However, the fact is that centrifugal ('deconcentration') forces, and primarily impacting recoil forces impact in such a way as to form cities with structures differing from those arising as a result of the highly focused gravity frequently defined as the centripetal or concentration force (cf. Fig. 6).

An important aspect in the discussion on the development of settlement systems is that the centripetal and centrifugal forces are of relatively local coverage. Hence, explanations regarding the development and functioning of cities invoke them within a limited range only. This would then be an explanation complementary

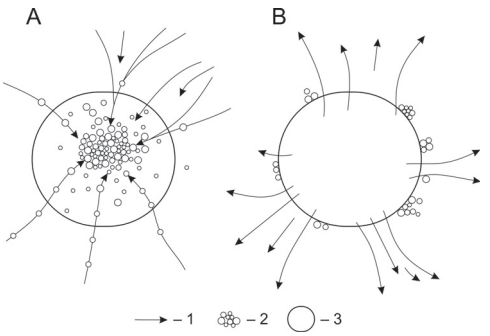

Figure 6. The city-forming point in the context of forces acting within an inertial frame (system) Symbols: 1 – Direction of centripetal forces (A) and centrifugal forces (B) in the case of their domination as primary forces (in inertial linkages), 2 – forms of concentration of settlement structure, 3 – the city-forming point.

to that which is, *de facto,* based on settlement systems of interacting gravity and recoil. It is thus evident that interpretation of the forces responsible for creating specific interactions in the socio-economic systems is no simple matter. Each time, study should consider the cause-and-effect relationship by reference to particular elements of the functional structure, as well as the specifics of network systems. The latter allows for the identification of which element is primary, and which is a consequence of existing economic structures in action. Methodological achievement based around the concept of the economic base is indisputably essential in the case of this issue.

However, this discourse still fails to provide an ultimate answer to the question posed in the introduction as to the true nature of the centripetal and centrifugal forces considered from the point of view of socioeconomic geography. How far does the reality of the scientific metaphor diverge from reality, in this case as perceived from the perspective of Newtonian mechanics? How far should it differ? And finally, which attributes ensure that there are greater or lesser discrepancies between what the laws of physics define and what is contained in the definitional scientific metaphor?

An attempt to address these questions should first seek to explain the nature

of centripetal and centrifugal forces referred to in geographical research, herein focused specifically on urban studies.

In fact analysis of achievements in this area with an 'averaging' of the scope of proposed definitions and applications of these concepts leads to the conclusion that:

- the centripetal force describes economic and social interactions, and those relating to spatial infrastructure, whose direction is oriented from the hinterland or the impact area of the city to the inner city, or the city itself;
- the centrifugal force determines the type of economic or social interactions, or interactions involving spatial infrastructure, that are directed from the inner city, or the city itself, towards a defined area of direct impact.

It is clear from these definitions, that what socioeconomic research *de facto* investigates is closer to the attribute of impact (in the broader sense) or interaction, as opposed to the attribute of mechanical force *per se*. If so, what is the causative agent behind this conceptual gap? Firstly, it is the fact that the reality in physicalistic terms has what is primarily a mechanistically-thermodynamic dimension. The role of metaphorical attributes of thermodynamics - diffusion, dissipation, flows, entropy and negative entropy – have been mentioned already. All of this ensures that, in settlement systems, city-forming forces exert an impact, not only on potential, but also on structure. Beyond that, the human social system is also superimposed onto this dimension. Its sociological, psychological and perceptual attributes lead to possible further 'scattering' of the role of impacts on a formed mechanistic level. A key consideration reflecting the specific nature of geographical research, is that physical phenomena operate in relation to attributes characterising solid, liquid or gaseous forms. However, if they are to be studied academically, these forms will always need to be homogeneous, while in fact geographical phenomena operate in geographical – (i.e. biotic, abiotic and anthropogeographical) space that is both heterogeneous vertically and variable in temporal terms.

The issue under discussion is thus by its very nature complex. Difficulties of interpretation arise largely as attempts are made to transfer clearly definable physical principles, with a view to diverse phenomena and geographical structures being described. Such a procedure in fact moves beyond 'difficult', in the direction of 'impossible', in some respects at least. Hence the contrast between the physical and geographical realities is alleviated by applying a scientific metaphor that need not always take full account of the complete picture of a secondary assertion in relation to the original statement. However, this truth denotes many ongoing research challenges arising from issues of centripetal and centrifugal forces discussed in this article. A particular challenge is to improve methods of spatial analysis to take the discussed elements into account. This is particularly important in the context of contemporary complicating and differentiating socio-economic and spatial structures.

Further conceptualisation at the level of ontological clarification is required where the unification of the thermodynamic and mechanistic paradigms is concerned. Although current achievements in explaining the specifics of these two paradigms separately are satisfactory, studies on co-dependence of the discussed elements explained using mechanistic and thermodynamic metaphors remain relatively under-represented. Functionalistic explanations should also play an important role (cf. Suliborski 2003), since these constitute an expected keystone between typically empirical works and those referring to ontological convention.

It would also be worthwhile popularising knowledge of the ontological basis underpinning the development of cities and regions using developed case studies, in particular in cases where the applicability of studies undertaken is made clear by their authors.

Editors' note:
Unless otherwise stated, the sources of tables and figures are the authors', on the basis of their own research.

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