# PLURIDISCIPLINARITY VS. INTERDISCIPLINARITY IN CIVIL ENGINEERING EDUCATION IN SEISMIC AREAS

*Emil-Sever GEORGESCU*[1], *Mihaela Stela GEORGESCU*[2]
[1]Ph.D. Engineer, Scientific Director for Constructions, National Institute "URBAN-INCERC", Bucharest, ssever@incerc2004.ro
[2]Ph.D. Engineer, Associate Professor, University of Architecture and Urban Planning „Ion Mincu", Bucharest, mgeorgescu@ipct.ro

**ABSTRACT**

Civil engineers are involved in building and maintaining a built environment that meets the sustainable development requirements. This environment is interdisciplinary in its nature, as it results from an interaction between different actors (architects, city planners, authorities, clients, civil engineers). Professional formation and training of engineers is a result of the didactic and technical efforts, which later will be reflected in the way constructions are being designed and built, so that engineers are not considered simple workers. Thus, when discussing professional formation and training of engineers, one should debate the necessary steps they have to take in their relationship with other disciplines. Practicing civil engineering in seismic risk areas in Romania adds specific requirements.

*Keywords*: multidisciplinarity; pluri-disciplinarity; transdisciplinarity; inter-disciplinarity; seismic zones

**REZUMAT**

Inginerii constructori sunt implicați în construirea şi menținerea unui fond construit care să respecte cerințele dezvoltării durabile. Acest mediu este în esență interdisciplinar, deoarece rezultă din interacțiunea între mai mulți specialişti (arhitecți, urbanişti, autorități, proprietari/clienți, ingineri constructori). Formarea profesională şi instruirea inginerilor este un rezultat al eforturilor de natură didactică şi tehnică, care mai târziu se va reflecta în modul cum se va proiecta şi construi, pentru ca inginerii constructori să nu fie percepuți ca simpli executanți. Astfel, când se discută de formarea şi instruirea profesională a inginerilor, ar trebui dezbătute etapele necesare de urmat în relația lor cu alte discipline. Practicarea ingineriei civile în zonele seismice din România necesită cerințe specifice.

*Cuvinte cheie*: multidisciplinaritate; pluridisciplinaritate; transdisciplinaritate; interdisciplinaritate; zone seismice

## 1. CIVIL ENGINEERING IN RELATION TO THE DEVELOPMENT OF INTERDISCIPLINARY RELATIONS

Civil engineers are involved in building and maintaining a built environment according to the requirements of sustainable development. This environment is basically a result of the action of several professions and/or disciplines, i.e. it is interdisciplinary and the result of interrelated actions of various actors (architects, city planners, authorities, clients, civil engineers). Professional formation and training of civil engineers is a result of the didactic and technical efforts, which later will be reflected in the way constructions are being designed and built, and seismic risk areas in Romania adds specific requirements.

On the historical development of professions involved in the act and art of building there is a rich literature starting with the so called "architecton" of the Greek and Roman antiquity. Nevertheless, we often forget that only one man was in charge of both conceptual and artistic sides, and in the same time he was also "architecton mehanicos", i.e. "engineer" and even master coordinator. That only some works enjoy particular attention and public recognition of a profession that is apparently different from art and today is called "engineering" can be very frustrating. The structural side of an architectural masterpiece is seldom considered, and it was believed that structural members that implicitly or explicitly contribute to the strength of buildings, including those subject to seismic actions, are based apparently only on tradition, best practices, expertise or perhaps intuition.

The recognition of “engineer” as a profession dates back to the seventeenth century and the first civil engineering school – the oldest engineering discipline after the military one – was established in the eighteenth century in France and it served as a model to the Romanian school of civil engineering (Georgescu, 2012).

Considering the reality of the current division of professions involved in the act of building, where architecture is a liberal profession under the authority of a professional order, while civil engineering is subject to strict rules of public institutions, e.g. structural safety standards, discussion is needed on the formation and training of engineers and other professionals, on topics related to the studied disciplines.

In this context, the steps to be taken should be discussed according to the relationship between different disciplines, starting with the following devoted terms (of Chynoweth, 2006, citing Jantsch, 1972, Klein, 1990 and others):

- multidisciplinarity – existence of various disciplines, which are available but the interdependency of which may not yet have been identified and which are not connected in a common approach, hence, summation without integration;
- pluridisciplinarity – existence of disciplines available in a particular sequence, partially with feedback elements, which are incompletely correlated but which are the first step towards integration;
- crossdisciplinarity – existence of links between some disciplines, which are not intentionally coordinated; an advanced pluridisciplinarity,
- interdisciplinarity – a common understanding of knowledge progress, with convergent principles, complex links between disciplines and multiple feedback elements.

These definitions are not unique, since there is a whole advanced research field of transdisciplinarity, emerging since the 1970’s, aiming at semantic and practical unification of these type of definitions and hierarchical ranking, therefore transdisciplinarity signifies a unity of knowledge beyond disciplines, across the different disciplines, and beyond each individual discipline (Charter of Transdisciplinarity, 1994; Nicolescu, 2002). As the goal of transdisciplinarity is the understanding of the present world, while our goal is to study the safe built environment, at a building, community, regional and country scale, we consider interdisciplinarity as a convenient semantic term and evolutionary step towards a global and worldwide approach.

Although this article is not a detailed analysis, what is significant is that the common opinion of the cited authors (Chynoweth, 2006, citing Jantsch, 1972, Klein, 1990) is that interdisciplinarity could be achieved when "traditional disciplines of knowledge are brought together into structures that reflect "basic themes or needed areas of society" and a common interest axiom facilitates integration, thus creating a new form of knowledge, commonly referred to as "interdisciplinary".

If we accept that creating a sustainable built environment is a basic issue of the Romanian society, with major constraints of seismic risk, and the current specialization and fragmentation has its disadvantages, we will be able to find didactic ways to achieve interdisciplinarity at university level, which will later be applied to facilitate interdisciplinary approaches to professions.

Regarding its historical development – from the establishment of the School of Bridges and Roads, the first technical college in Romania, which was later included into the Polytechnics University and the Civil Engineering Institute - Technical University of Civil Engineering Bucharest (ICB-UTCB - www.utcb.ro) – a basic structure of disciplines made itself conspicuous over time; it reflects conservatism, with positive or negative effects on many disciplines. Other universities in the country have the same structure and we will not go into the details of curriculum. Pluridisciplinarity is basically reflected in the structure of teaching, according to faculty, curricula and years of study. Transdisciplinarity is obvious in the sequence of certain courses by year of study.

If we refer to the faculties of civil engineering (e.g. UTCB), interdisciplinarity is partly achieved by:

- courses in urban engineering departments (environmental engineering, infrastructure, urban metabolism);
- assessment of structural safety and seismic risk, partly covered by bachelor and/or master's courses for engineers, courses in foreign languages etc.;
- applied economics to engineering, which already include a specialization;
- construction history, which can become a regular course;
- theoretical and applied research in the field, with the participation of teaching staff in projects in partnership with other universities and research institutes.

There are also areas where interdisciplinarity is not used enough, such as:

- geotechnics, where teams are sometimes quite different from those concerned with seismology;
- graduation theses, in the specific field of the particular department of the coordinating teacher;
- master and doctoral courses and acknowledged post-graduate courses;
- areas of doctoral studies where the lists of scientific coordinators are not complete.

On the other hand, it is interesting how architects, the main partners of engineers, are trained in a certain complementarity. There was a time when the formation of architects in terms of structural engineering was insistently and rigorously promoted (1960...2010 by Professor Alexandru Cişmigiu and then by Professor Dr. Radu Petrovici) in the University of Architecture and Urban Planning "Ion Mincu" (www.uauim.ro), while the current approach is closer to architecture schools of the "Fine Arts" type in areas of moderate seismicity.

Nonetheless, architects have to take part in this process, as Chapter 10 of the Seismic Design Code 100-1/2006 P - Part I: "Design provisions for buildings MTCT-UTCB" contains Specific provisions for non-structural members of buildings (author Professor Dr. R. Petrovici).

Since 2005, the Faculty of Interior Architecture has introduced as a compulsory course on "Structural/non-structural" – ST-42 (http://www.uauim.ro/facultati/interior/interior/.../st-42/, Georgescu, M., 2005), which is aimed at:

- assimilation of concepts required to harmonize and match interior design with the composition and behaviour of structural and non-structural members in building;
- basics of load bearing in building, proper configuration of buildings with construction systems that are currently used, structure and design of joints in seismic risk areas;
- basics of structural and non-structural member configuration, structure and size, and equipment mounting on such members;
- identifying structural and non-structural members; current flaws, precautions and restrictions in case of intervention ;
- applying the concepts of mechanics, statics and structural strength to structural and non- structural wood or steel members.

Thus, interdisciplinarity has a higher level, which is to be preferred, provided a continuum of knowledge is ensured and that the process, as a target of knowledge and learning processes should not be confined to education and training for one profession.

## 2. EXAMPLES OF WHY INTERDISCIPLINARY VISIONS ARE NEEDED

A first example of the history of architecture, civil engineering and seismic engineering is the collapse of Carlton building in the earthquake of November 10, 1940. This was the great surprise and urban disaster of the time, as it was the first earthquake "victim", the first collapse of a tall modern concrete structure in Europe, especially in a Vrancea earthquake. The building was a representative work of the time – designed by GM Cantacuzino, a famous architect of the new generation –, the highest reinforced concrete building in Bucharest and in the country (after the Telephone Palace – a steel structure building). Today, more than 70 years after the collapse, it still makes the subject of engineering and architectural debates on allowable height and architectural structure under the land conditions of the capital city (e.g. the type of land that would amplify oscillations, i.e. the contribution of groundwater level), and many aspects were not fully understood until the earthquake of 1977 (Georgescu, 2005, 2007; Georgescu and Pomonis, 2011).

The process that followed has revealed an adversity between engineers and architects having differing technical opinions, with contradictory arguments; it is worth mentioning that the architects of the time played a very important role in the building process, and had divergent interests from the civil engineers of the building company, where Professors Hangan and Beles were the structural engineering experts (Georgescu, 2007). Civil engineers belong to different generations and schools, and at that time, earthquake resistance appeared to be an attribute that does not necessarily require calculations. We know now that the urban development of the city centre until 1940, although based on an urban plan which was implemented after 1935, could not include seismic protection concerns. In the absence of local mandatory standards it was difficult to establish – given the general interpretation of requirements at the time – dissociated liability, so the architect was subject, to a certain extent, to the rigour of the law.

As regards the other professions, in 1940 it was noticed that although Romania had a long history of seismic events, there was no interest in the subject and there was little knowledge about the Vrancea seismic centre. In 1940, the earth sciences used to supply knowledge about the causes, location, manifestation and magnitude of the earthquakes, but there was no communication between geologists and earthquake specialists and architects or structural engineers of the epoch in relation to the seismic behaviour of buildings subjected to dynamic actions.

However, building engineers consider the November 10, 1940 earthquake a vector of the birth of modern earthquake engineering in Romania, because it gave rise to questions and concerns in both seismology, and reinforced concrete structure engineering as well as in architecture and urban planning. For a long time, the disjunction of the urban planning concerns from those of civil engineering, and of the two from the management of disasters represented a source of serious under-evaluation of the casualty potentials, that accumulated up to a level difficult to subsequently counteract (Georgescu, 2007).

Another example is the April 6, 2009 earthquake of Abruzzo, Italy, in L'Aquilla, with the focus at 10-12 km depth and magnitude $M_L$ = 5.8 or $M_W$ = 6.3. As a result of the collapsed buildings and severe building damages, some 300 peoples died and about 1,500 persons were injured. A large number of heritage buildings in the historical centre of the city were deteriorated. Many old low-quality and poorly maintained load-bearing masonry buildings suffered damages or collapsed partially or totally. However, relatively new reinforced concrete buildings were also damaged or collapsed because of design errors or mistakes. A public case was that of the reinforced concrete buildings that did not suffer important damages in their reinforced concrete structure, but whose non-structural components were so badly damaged that they were declared uninhabitable, as they represented a serious threat for the life of the people and the decision was to evacuate the city.

In fact, the thin hollow brick back-up masonry walls, and / or the exterior and partition walls suffered so severe damages, that they were displaced from the frameworks and collapsed inside or outside the building.

The visible explanation was given by the three–layered walls, with air or mineral wool between layers, but without any reinforcement or additional ties among them. It is obvious that the building solutions and practices applied had been accepted by both the architects, the building engineers and the authorities as fit for thermal insulation, but they had not been tested for earthquake resistance (Georgescu et al, 2009).

On 27 February, 2010, the Maule, Chile, earthquake (Mw 8.8) occurred off the coast of the Pacific Ocean. Collapses of buildings in the Santiago City and other cities, damages to hospitals, bridges and viaducts were reported. Some 450 people died, hundreds of people were missing and 1.5 to 2 million people remained homeless. Chile is particularly interesting from a civil engineering point of view, as earthquake engineering and building engineering are very developed and more than 70 years of efforts were made in the controlled application of the advanced codes of seismic design. Therefore, most of the buildings designed under controlled seismic rules had a good response to the seismic actions.

It is worth mentioning that in the '70s Romania and Chile were among the first countries in the world to have applied the building solution of reinforced concrete structural walls. From an engineering point of view, in 2010, an investigation of the damages to the buildings based on this type of structure in the Conception City revealed that the cross reinforcement was not well-adapted to the size of the buildings and in some of the buildings erected after 1985 the wall thickness was not proportionally increased to reflect the height of the buildings!!!! The relatively ductile behaviour of most of the buildings indicated that the response of those buildings was not entirely deficient, but the lack of the flanges at the end of the structural walls generated the damages. In most of the damaged walls, the end bars were not confined with stirrups, and the horizontal bars had no hooks (Georgescu et al, 2010).

The damages were also the result of architectural errors. There were buildings with 'weak ground floor' or deficient architectural-structural design that suffered severe damages. In most high-rise reinforced concrete buildings, the longitudinal structural walls were placed on both sides of the corridor, allowing open spaces to the exterior of the building, parking spaces at the basement and open spaces for curtain walls above the ground floor. The cross structural walls, whose role is to take over the shear forces, were frequently placed at regular distances on each side of the corridor. Some of the walls were limited to the ground floor only, thus reducing the structural redundancy and ignoring the actual dynamic behaviour of the structure. The overall configuration indicated a decisive role of the walls, which took over the seismic forces from the earthquake shaking in the transverse direction. It has to be mentioned that in the old and low-rise buildings there were thicker walls placed at shorter distances and most of them showed no damage, but it appears that the good response of the buildings to the 1985 earthquake made architects and structural engineers unreasonably trustful to increase the height of the buildings (Georgescu et al, 2010).

It follows from the above examples that the responsibility in finding reliable solutions for diminishing the seismic risk devolves not only on the specialists in structural engineering, but also on the specialists in urban engineering, architecture and urban planning, public administration and disaster management. We can say that each profession can have different views and priorities, but not in relation to the seismic risk. In a seismic area, the solution for urban remodelling must be carefully selected and correlated with the General Urban Plan, where the solution for urban reconstruction following damages and destructions should be conceived in advance (Georgescu 2007, Georgescu et al, 2008, 2010). If we intend to avoid such effects in the future, the engineering interdisciplinarity has a great development potential in correlation with: - architecture and urban planning, areas with which contacts are less visible at present (engineering aspects of spatial development, infrastructure);

- disaster prevention management and study of several extreme events (explosions, terrorism, fires in high-rise buildings and at urban scale);
- technological sciences, covering relatively classical knowledge;
- general legislation and technical regulations in the field,
- the requirements of sustainable development, which have a different specific character in the different basic fields.

## 3. OPPORTUNITIES VERSUS POSSIBLE GAPS IN THE IMPLEMENTATION OF THE BOLOGNA PROCESS

At present, in Romania, where the Bologna process has been enforced by the law as a reform and new strategy in the higher education system, students are first attracted to pluridisciplinarity and transdisciplinarity, through compulsory subjects of study associated with several elective/ optional subjects, with possible delays of completing course units until the final year of study, the criterion being a certain number of credits.

In our opinion, universities should not exaggerate the role of credits for alternative options to degree level of study without defining the various options that have to be correlated to ensure interdisciplinarity, as a common concept of advance in knowledge, with convergent principles, complex connections between subjects of study and multiple feedback elements.

The transition to a higher-education system including three or four years of study for undergraduates (Bachelor degrees) followed by a number of years of study for graduates (Master degrees and Ph.D. degrees) imposes a careful analysis of the relationship between the curricula of the basic years of study and that of the next steps in the lifelong learning, in order to ensure a broader understanding of the relations between the fields of study. The mobility of the students and specialists within the European Union area should not neglect the particular specificity of Romania's earthquake prone territory, and architects and engineers should avoid thoughtless application of architectural and building knowledge and solutions adopted from other seismic zones. The use of modern building concepts and materials should not include curtain walls that burn or fall in an earthquake event or are pulled out by wind and even endanger the neighbouring heritage buildings.

Modernism and post-modernism in building can be considered in relation to both the evolution of styles in architecture and the need to meet the requirements of a user-friendly architecture and the identification of the trends that at a certain moment make the maxim "form follows function" invalid and as a consequence the capacity to cope with the new types of combinations in structures. In engineering terms, modernity should mean a satisfactory ability to understand in a critical manner and to innovate, to develop and apply new materials, structural and non-structural building solutions in relation to the market evolution and the society needs, for instance high-strength concrete, super high-rise buildings, very-long span bridges, energy efficient and / or passive houses. It should particularly favour the development of new technologies, for example basement insulation methods, diagonal damping systems, intelligent domotic systems. For compatibilization with other specialists, a broader culture of the graduates in the area would be useful in order to ease their integration into different work teams of various institutions.

Our suggestions regarding the partnerships with recognized professionals in interdisciplinarity areas of other universities or national research institutes in the educational and training process include:

- inviting such professionals as lecturers to deliver courses, to be members in the examination panels of the diploma papers and/ or theses, or as members in the examination panels of the doctoral theses, examination of the theses and oral examination;
- guided practice or visit of the students and graduates, candidates to a master's degree

or candidates to a doctor's degree to the laboratories of recognized research institutes.

## ACKNOWLEDGEMENTS

A version of this paper was presented at The Fourth Edition of the National Research Conference on Constructions, Economy of constructions, Architecture, Urbanism and Territorial Development "Multi-, Inter- and Trans-Disciplinary Approaches to Urbanism, Architecture and Constructions", October 19th, 2012, URBAN-INCERC, Bucharest, Romania.

## REFERENCES

1. Charter of Transdisciplinarity (1994). Centre International de Recherches et Études Transdisciplinaires, http://perso.club-internet.fr/nicol/ciret/.
2. Chynoweth, P. (2006), *The Built Environment Interdiscipline: A Theoretical Model for Decision Makers in Research and Teaching. Construction sustainability and innovation*. Proceedings of the CIB Working Commission (W089) Building Education and Research Conference 2006 (BEAR 2006). Kowloon Shangri-La Hotel, Hong Kong, 10 – 13 April 2006. The Hong Kong Polytechnic University.
3. www.utcb.ro. Universitatea Tehnică de Construcţii Bucureşti. www.uauim.ro. Universitatea de Arhitectură şi Urbanism "Ion Mincu", Bucureşti. www.uauim.ro/facultati/interior/interior/.../st-42
4. Georgescu, E. S. (2005), *Managementul riscului seismic: specific, percepţie şi comunicare*. Editura Fundaţiei Culturale LIBRA, Bucureşti. ISBN 973-8327-96-2; volum apărut cu sprijinul Ministerului Educaţiei şi Cercetării.
5. Georgescu, M. (2005), *Relaţia structural – nestructural în proiectarea de arhitectură*. Editura Universitară "Ion Mincu", Bucureşti, 2005, ISBN 973-7999-46-0
6. Georgescu, E. S. (2007), *Bucureştiul şi seismele*. Editura Fundaţiei Culturale Libra, Bucureşti. ISBN: 978-973-7633-45-50-7. Volum apărut cu sprijinul Autoritatii Naţionale pentru Cercetare Ştiinţifică.
7. Georgescu, E. S. (2012), *De la inginer la om de ştiinţă, sau despre vulnerabilitatea şi invincibilitatea cercetătorului din ingineria seismică*. Domnului Prof. Dr. Ing. Dr. H. C. Horea Sandi, la aniversarea a 80 de ani. Urbanism, Arhitectură, Construcţii, Vol.3, Nr. 2, 2012, pp. 91-98.
8. Georgescu, E. S, Georgescu, M. S., Albota, E. (2008), *Structural and life safety alternatives in urban landscape under extreme actions in seismic zones of Romania*. Proc. The 14th World Conference on Earthquake Engineering, Beijing, China, October 12-17, 2008.
9. Georgescu, E. S, Georgescu, M. S., Albota, E. (2010): *Towards a multi-hazard engineering and architectural-urbanistic design in seismic zones of Romania*. Proceedings 14 ECEE, Ohrid, Macedonia 2010.
10. Georgescu, E. S., Dragomir, C. S. (2009): *Investigarea integrată a efectelor cutremurului din 6 aprilie 2009 asupra construcţiilor din zona L'Aquila, Abruzzo, Italia şi învăţămintele pentru situaţia din România*. A 4-a Conferinţă Naţională de Inginerie Seismică, decembrie 2009.
11. Georgescu, E. S., Dragomir, C. S., Borcia, I. S., Dobre, D. (2010): *Cutremurul Mw 8,8 Maule – Chile din 27 februarie 2010: analiza preliminară a datelor seismografice, prăbuşirilor şi avariilor la clădiri*. A XX-a Conferinţă Naţională AICPS, 28 mai 2010, Hotel Athenee Palace Hilton, Bucureşti
12. Georgescu, E. S., Pomonis, A.: *Emergency management in Vrancea (Romania) earthquakes of 1940 and 1977: casualty patterns vs. search and rescue needs*. Proceedings of TIEMS - The International Emergency Management Society, 18th Annual Conference 2011
13. Georgescu E. S., Tojo, I., Stamatiade, C., Iftimescu, R., Vladescu, C., Negulescu, C., Radoi, R. (2004): *Japan - Romania knowledge transfer for earthquake disaster prevention preparedness of citizens in Bucharest*, Proc. 13 th WCEE, August 1st-6-th, 2004, Vancouver, British Columbia, Canada.
14. Georgescu, E. S. (2004): *Forensic engineering studies on historical earthquakes in Romania*, Proc. 13 th WCEE, August 1st-6-th, 2004, Vancouver, British Columbia, Canada.
15. Nicolescu, B. (2002): *"Manifesto of Transdisciplinarity"*, State University of New York Press, New York, USA.
16. P 100–1/2006. Cod de proiectare seismică – Partea I: Prevederi de proiectare pentru clădiri. MTCT-UTCB.