

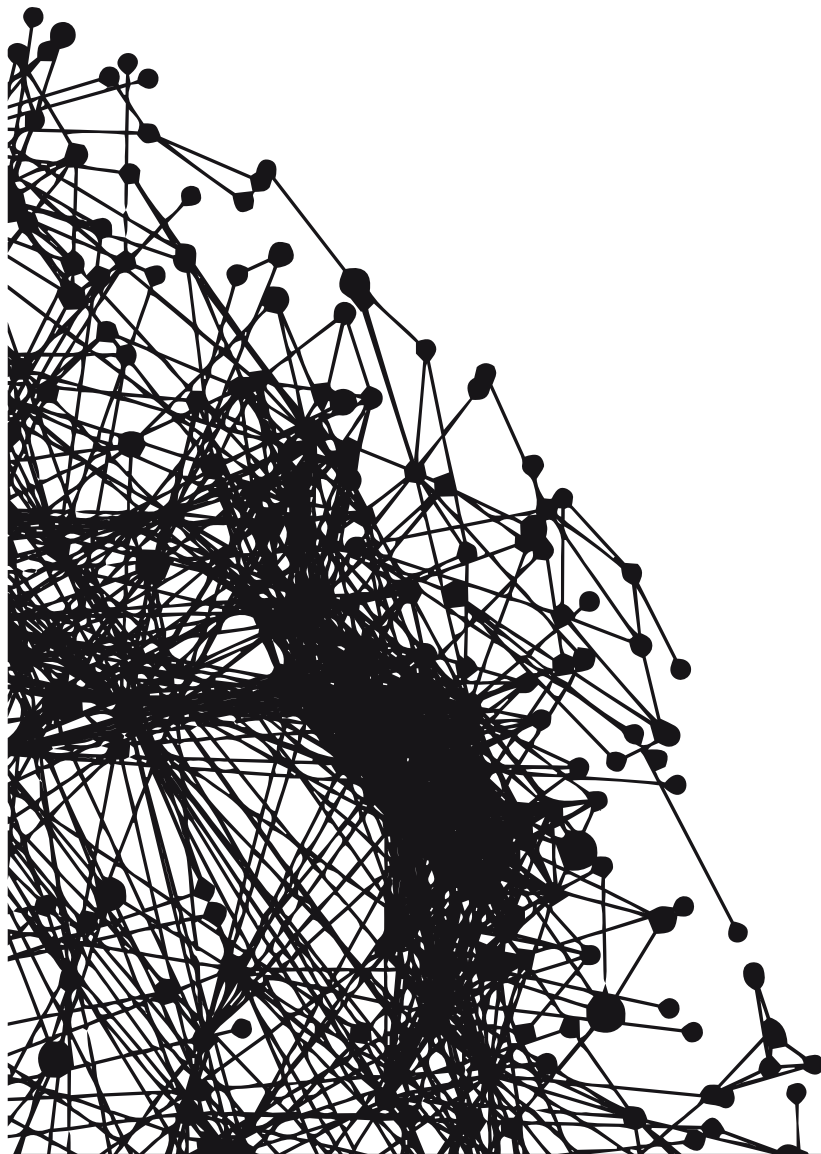
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PLACES AND TECHNOLOGIES 2014

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editors:

Eva Vaništa Lazarević, Aleksandra Đukić,  
Aleksandra Krstić - Furundžić, Milena Vukmirović

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# PLACES AND TECHNOLOGIES 2014

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# CONTENTS

## PART I: URBANISM

### **Urban planning and technologies**

#### **OVERCOMING BARRIERS TO GROWTH**

Stephen Platt 16

#### **URBAN CHALLENGES OF ENERGY EFFICIENCY AND CONTEXT-SENSITIVE PLANNING APPROACHES IN BULGARIA**

Elena Dimitrova 25

#### **NEW URBAN PROTOCOLS FOR FRAGMENTED TERRITORIES \_ THE EXAMPLE OF WESTERN THESSALONIKI**

Styliani Rossikopoulou-Pappa, Valia Fragkia 33

#### **A FEASIBILITY STUDY FOR A TECHNOLOGICAL PARK IN FALCONARA MARITTIMA AN, ITALY**

Giovanni Sergi 41

#### **SAVING URBAN PLANNING FROM ANOTHER UTOPIAN MODEL**

Danijela Milojkić, Marija Maruna 48

#### **THE IMPLICATIONS OF DIGITAL TECHNOLOGY ON THE PERCEPTION OF CENTRALITY**

Mihai Alexandru, Cătălina Ioniță 56

#### **TECHNOLOGY AND LANDSCAPE: REDUCE, REUSE AND RECYCLE THE MINING DROSSCAPES**

Nicola Martinelli, Francesco Marocco, Alessandro Reina, Maristella Loi, Federica Greco 63

#### **THE ILLEGAL SETTLEMENTS IN BELGRADE VS. TAMING CITY GROWTH: CASE STUDY OF BELGRADE**

Biserka Mitrović, Miodrag Ralević, Branislav Antonić 71

#### **IMPACT OF CLIMATE CHANGE IN URBAN PLANNING**

Tamara Tošić 78

#### **CONCEPT OF URBAN VILLAGE: THE APPLICATION OF THE CONCEPT AS A FOUNDATION FOR NEW TYPOLOGY OF URBAN VILLAGES**

Branislav Antonić 85

#### **RESILIENCE AND VULNERABILITY OF URBAN SYSTEMS. A METHODOLOGICAL PROPOSAL FOR SEISMIC RISK MITIGATION**

Rigels Pirgu 94

## **Urban design and technologies**

<b>PUBLIC PLACES AND SPLIT DEVELOPMENT MODEL</b> Višnja Kukoč	103
<b>AGILE LANDSCAPES: REDESIGNING URBAN SPACE</b> Anastasios Tellios, Despoina Zavraka	110
<b>PLANNING AND DESIGNING SAFE AND SECURE OPEN PUBLIC SPACES IN SERBIA</b> Svetlana Stanarević, Aleksandra Djukic	118
<b>SPATIAL AND FUNCTIONAL TRANSFORMATION OF BUSINESS AREAS UNDER THE IMPACT OF INFORMATION TECHNOLOGIES – CASE STUDY OF NIŠ ADMINISTRATIVE DISTRICT</b> Aleksandar Ristić, Petar Mitković	130
<b>THE IMPACT OF NEW TECHNOLOGIES ON CITY ACUPUNCTURE METHODOLOGY AND INTERVENTIONS</b> Kristina Careva, Rene Lisac	138
<b>COMFORT OF OPEN PUBLIC SPACES: CASE STUDY NEW BELGRADE</b> Aleksandra Djukic, Nevena Novakovic	145
<b>005 PUBLIC ART IN BERLIN</b> Biljana Arandjelovic	151
<b>PROTECTION OF PERSON WHIT DISABILITIES: IMPLEMENTATION OF ACCESSIBILITY STANDARDS</b> Dragana Vasiljevic Tomic, Radojko Obradović	160
<b>VERTICAL PUBLIC SPACE</b> Sorana Cornelia Radulescu, Roger Riewe	167
<b>READY-AVAILABLE HYBRID METHODOLOGIES FOR CONTEMPORARY PUBLIC SPACE RESEARCH</b> Milena Ivkovic, Berit Piepgras, Robin van Emden	175
<b>RETAIL – NEW TECHNOLOGIES AND URBAN CENTRALITY</b> Martin Brabant	181
<b>TECHNOLOGY AND NEOLIBERAL URBAN PLACES</b> Marija Cvjetković	191
<b>NEURAL CITIES OR HOW CITIES TEACH US TO DESIGN THEM BETTER</b> Angelica Stan	198
<b>MORPHOLOGICAL AND TYPOLOGICAL CLASSIFICATION OF GREEN STREET FORMS: MLADEN STOJANOVIC STREET IN BANJA LUKA</b> Tanja Trkulja	206

## **Urban regeneration and technology**

### **PROPERTY ISSUES IN THE TURKISH URBAN REGENERATION PROJECTS**

Mehmet Çete, Yunus Konbul 215

### **URBAN ENERGY AND URBAN REGENERATION STRATEGIES: EVALUATION OF IZMIR-UZUNDERE URBAN REGENERATION PROJECT**

Yakup Egercioğlu, Çilem Türkmen 222

### **THE EMPTY URBAN SPACES AS AN OPPORTUNITY FOR THE CITY TO REINVENT ITSELF: THE CASE OF THE INDUSTRIAL TECHNOLOGICAL OBSOLETENESS**

Cătălina Ioniță, Mihai Alexandru 230

### **ENHANCEMENT OF URBAN LIFE QUALITY IN URBAN REGENERATION PROJECTS: IZMIR-BAYRAKLI URBAN REGENERATION PROJECT**

Yakup Egercioğlu, Tuğçe Ertan 238

### **THE INDUSTRIAL BUILDINGS WHICH USED IN SAUDI ARABIA AND SUSTAINABILITY**

Wael Al-Buzz 246

### **AN OVERVIEW OF URBAN REGENERATION PROJECTS IN TURKEY**

Yunus Konbul, Mehmet Çete 257

### **ART AND CULTURE AS INITIATORS OF ARCHITECTURAL AND URBAN TRANSFORMATION IN SAVAMALA**

Ksenija Pantović, Iva Čukić, Jasna Kavran 265

## **Smart cities/regions and network protocols**

### **SMART CITY GRAZ: FROM THE VISION TO THE ACTION**

Carlos Varela Martín, Ernst Rainer, Hans Schnitzer 276

### **RESIDENTS INTERACTION WITH HOME RESOURCES**

Cerasela Dinu, Constantin-Daniel Oancea 285

### **RENEWABLE AND DISTRIBUTED SOURCES WITHIN SMART ENERGY REGIONS**

Jovan Todorovic 293

### **THE SMART CITY FOR THE FUTURE. HOW A SPATIALLY ENABLED AFFECTED BY THE URBAN POPULATION?**

Shahryar Habibi 300

### **PERFORMANCE EVALUATION OF ROUTING PROTOCOLS FOR AD-HOC NETWORKS**

Ledina Karteri, Valma Prifti 306



<b>SMART CITIES AND CHALLENGES OF SUSTAINABILITY</b>	
Rigels Pirgu	315
<b>A FUZZY BASED CALL CONTROL SYSTEM IN MOBILE NETWORKS, CONSIDERING PRIORITY COMMUNICATIONS</b>	
Valma Prifti, Ledina Karteri	323
<b>Historical centers, Building heritage and Technologies</b>	
<b>ICT AND VGI TO PROMOTE MINOR HISTORIC CENTRES AND THEIR LANDSCAPE</b>	
Pierangela Loconte, Francesco Rotondo	331
<b>THE SUSTAINABILITY AND CULTURAL HERITAGE MANAGEMENT</b>	
Christian Kersten Hofbauer, Elham Madadi Kandjani, Jean Marie Corneille Meuwissen	339
<b>CONCEPTS OF FORMING OF URBAN SOLUTIONS IN HOUSING SETTLEMENTS IN BELGRADE BUILT IN PRECAST INDUSTRIALIZED SYSTEMS IN SECOND HALF OF XX CENTURY</b>	
Dragana Mekanov	346
<b>NEW ARCHITECTURE IN HISTORICAL CENTRES</b>	
Alessandro Bruccoleri	355
<b>INFORMATION AND COMMUNICATION TECHNOLOGIES TO IMPROVE THE KNOWLEDGE OF PLACES. THE ROME HISTORICAL CENTRE AS A CASE STUDY</b>	
Francesca Geremia	363
<b>CONTEMPORARY INTERVENTIONS IN HISTORIC PLACES _ THE EXAMPLE OF THESSALONIKI METRO</b>	
Stavros Apotsos	372
<b>Image and Identity of place</b>	
<b>THE IMAGE OF TRIFKOVIĆ SQUARE (NOVI SAD, SERBIA) THEN AND NOW</b>	
Ivana Blagojević, Ksenija Hiel	380
<b>IDENTITY OF NEW MEDIA SPACES</b>	
Jelena Brajković, Lidija Đokić	388
<b>THESSALONIKI: A MULTICULTURAL ARCHITECTURAL DESTINATION</b>	
Niki Manou-Andreadis, Maria Milona	400
<b>ELEMENTS OF IDENTITY AND UNUSED POTENTIALS OF CENTRAL ZONE IN NOVI SAD</b>	
Milena Krklješ, Dijana Apostolović, Aleksandra Milinković	408

<b>BELGRADE SKYLINE: CONTINUITY, PARADOXES &amp; DESIRES</b> Vladimir Milenković, Snežana Vesnić, Tatjana Stratimirović	416
<b>CITY OF THE MIND - INVISIBLE IN THE MAP</b> Jelena Stankovic, Milenko Stankovic	424
<b>WHAT MAKES A PLACE?</b> Saskia I. de Wit, Denise Piccinini	432
<b>SUSTAINABILITY, IDENTITY AND ROLE OF TRADITIONAL MATERIALS</b> Olivera Ilić Martinović, Mirjana Miletić	441
<b>IDENTITY OF URBAN SPACES; ASSESSMENT AND EVALUATION</b> Elham Madadi-Kandjani, Christian Kersten Hofbauer, Jean Marie Corneille Meuwissen	448
<b>IMAGE OF SUSTAINABLE PLACES</b> Vladimir Parežanin, Miloš Mihajlović	456
<b>PRESERVATION OF IDENTITY OF SPACE WITHIN RAPID ECONOMIC AND TECHNOLOGICAL DEVELOPMENT OF TOURIST DESTINATIONS IN THE EXAMPLE OD JIJOCA DE JERICOACOARA IN BRAZIL</b> Maja Momirov	469
 <b>PART II: ARCHITECTURE AND TECHNOLOGIES</b>	
<b>Sustainability, Sustainable buidings and technologies</b>	
<b>SUSTAINABLE RETROFITTING OF EXISTING AND HISTORIC BUILDINGS</b> Marina Traykova, Tanya Chardakova	477
<b>OSMOTIC LANDSCAPES - RECOVERED IDENTITIES</b> Venetia Tsakalidou, Anastasia Papadopoulou	485
<b>DESIGN SCENARIOS FOR AN OFFICE BUILDING – ENERGY AND ENVIRONMENTAL ASPECTS</b> Aleksandra Krstic-Furundzic, Tatjana Kosic	493
<b>TECHNOLOGICAL AND ENVIRONMENTAL ASPECTS OF RAPID HOUSING CONSTRUCTION</b> Nikola Macut, Bojana Stanković, Nataša Ćuković-Ignjatović	507
<b>ENERGY ANALYSIS AND REFURBISHMENT STRATEGY FOR ZAGREB UNIVERSITY BUILDINGS: FORMER FACULTY OF TECHNOLOGY IN ZAGREB BY ALFRED ALBINI</b> Stanka Ostojić, Zoran Veršić, Iva Muraj	515

<b>SUSTAINABLE REUSE OF OLD STRATEGIC INFRASTRUCTURE CANAL DANUBE-TISA-DANUBE</b>	523
Mirjana Jočić, Nataša Kuburović	
<b>PLACE ATTACHMENT AS POTENTIAL FOR SUSTAINABLE LOCAL DEVELOPMENT IN SERBIA</b>	533
Anđelka Mirkov	
<b>LOW ENERGY BUILDINGS: CONCEPT OF ENERGY PERFORMANCE OPTIMIZATION OF SINGLE-FAMILY HOUSES</b>	540
Katarina Slavković	
<b>TECHNOLOGY AND PRODUCTIVE PROCESS: MINING REJECTIONS FROM WASTE TO SUSTAINABLE RESOURCE</b>	549
Vincenzo Paolo Bagnato, Giovanna Mangialardi, Silvana Milella, Michele Mundo	
<b>ADAPTATION OF AN INDUSTRIAL BUILDING INTO HIGHER EDUCATION INSTITUTION IN ACCORDANCE WITH IMPROVED ENERGY PERFORMANCE</b>	557
Branko Slavković, Komnen Žižić, Danilo Dragović	
<b>FUNCTION OF A DESOLATE SPACE</b>	565
Aleksandra Pešterac, Daniela Dimitrovska	
<b>ENVIRONMENT CERTIFICATION OF REHABILITATION DESIGN PROJECTS: PUT AND SHU BUILDINGS AS CASE STUDY</b>	570
Florian Nepravishhta, Gerta Veliu, Ramadan Alushaj	
<b>Green strategies and technologies</b>	
<b>GREEN URBAN STRATEGIES IN THESSALONIKI IN THE CONTEXT OF CRISIS</b>	580
Evangelia Athanassiou	
<b>GEOSCIENTIFIC EDUCATIVE CENTRE AS SUSTAINABLE COMMUNITIES BUILDING MODEL – POSITIVE COOPERATION EXAMPLE OF LIKA-SENJ COUNTY (CROATIA) AND UNA-SANA COUNTY (BIH)</b>	587
Ivan Brlić, Anita Bušljeta-Tonković, Katarina Milković	
<b>THE OCCUPANTS' PERSPECTIVE AS CATALYST FOR LESS ENERGY INTENSIVE BUILDINGS</b>	597
Lucia Martincigh, Marina Di Guida, Giovanni Perrucci	
<b>THE COLLECTIVE SELF ORGANIZED HOUSING EXPERIENCE IN ITALY</b>	605
Silvia Brunoro, Giacomo Bizzarri	

<b>APPLICATION OF ROOF GARDENS IN THE DEFINING IMAGE OF THE CITY</b>	
Mirjana Sekulić, Bojana Stanković, Ljiljana Dosenović	613
<b>STRATEGY FOR NATIONAL DEFINITION OF NEARLY ZERO ENERGY BUILDINGS</b>	
Milica Jovanović Popović, Bojana Stanković, Jasna Kavran	621
<b>ENERGY OPTIMIZATION OF THE BUILDING ENVELOPE OF THE REPRESENTATIVE SAMPLE OF THE EXISTING RESIDENTIAL BUILDING IN BANJA LUKA</b>	
Darija Gajić, Aleksandra Krstić – Furundžić	629
<b>BLUE GREEN DREAM AND DAYLIGHT</b>	
Srdjan Stankovic, Cedo Maksimovic, Milenko Stankovic	637
<b>POSSIBILITIES FOR ENERGY REHABILITATION OF TYPICAL SINGLE FAMILY HOUSE IN BELGRADE – CASE STUDY</b>	
Bojana Stanković, Dušan Ignjatović, Nataša Ćuković-Ignjatović	646
<b>BLUE-GREEN INTEGRATED MODELING SOLUTIONS IN URBAN PLANNING AND ARCHITECTURAL DESIGN</b>	
Miloš Mirosavić, Ivana Mirosavić, Srđan Stanković, Čedo Maksimović, Ranko Božović	654
<b>POTENTIALS AND LIMITATIONS FOR ENERGY REFURBISHMENT OF MULTI-FAMILY RESIDENTIAL BUILDINGS BUILT IN BELGRADE BEFORE THE WORLD WAR ONE</b>	
Ljiljana Đukanović, Ana Radivojević, Aleksandar Rajčić	661
<b>FROM BUILDING INFORMATION MODELS TO SIMPLIFIED GEOMETRIES FOR ENERGY PERFORMANCE SIMULATION</b>	
Daniel Ladenhauf, René Berndt, Eva Eggeling, Torsten Ullrich, Kurt Battisti, Markus Gratzl-Michlmair	669
<b>ENERGY CITY GRAZ - REININGHAUS: FIRST RESULTS FROM AN ENERGY SELF-SUFFICIENT QUARTER</b>	
Heimo Staller, Ernst Rainer, Carlos Varela Martín	677
<b>ENERGY EFFICIENCY AS ADVANCED TECHNOLOGY FOR A SOLUTION TO THE PROBLEM OF DEPOPULATION OF RURAL AREAS IN SERBIA</b>	
Jovana Stanišić	684
<b>THE ENERGY EFFICIENT CITY</b>	
Ivan Dochev	692

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**INVESTIGATION OF FLY ASH INFLUENCE ON CEMENT MORTARS PROPERTIES**

Dragica Jevtić, Aleksandar Savić 701

**INFLUENCE OF GLASS COMPONENT JOINTS ON THE STRUCTURAL GLASS FACADE DESIGN**

Aleksandra Krstic-Furundzic, Tatjana Kosic, Jefto Terzovic 709

**QUANTIFYING THE THERMAL BRIDGING EFFECT WITH REGARD TO THE FAÇADE'S CONFIGURATION**

Katerina Tsikaloudaki, Theodore Theodosiou, Dimitris Aravantinos, Karolos Nicolaos Kontoleon, Dimitrios Bikas 720

**THE INFLUENCE OF NEW TECHNOLOGIES ON MODERN CITY FACADES**

Jasna Čikić Tovarović, Jelena Ivanović Šekularac, Nenad Šekularac 728

**DYNAMIC APPEARANCE OF URBAN AND ARCHITECTURAL SURFACES**

Tihana Hrastar, Tamara Marić, Bojana Bojanić 736

**TOWARDS GENERATIVE CONVERGENCE IN DESIGN OF ARCHITECTURAL STRUCTURES**

Jelena Milošević, Zoran Šobić, Miodrag Nestorović 744

**APPLICATION OF WOOD AS AN ELEMENT OF FACADE CLADDING IN CONTEMPORARY ARCHITECTURE OF BELGRADE**

Jelena Ivanović Šekularac, Jasna Čikić Tovarović, Nenad Šekularac 752

**COMPARISON OF INSULATION APPLIED ON SURFACES OF MODEL PLACED IN THE AREA OF SKOPJE**

Aleksandar Petrovski, Todorka Samardzioska, Ana Trombeva Gavriloska 758

**APPLICATION AND EFFECTS OF PHASE CHANGE MATERIALS IN A MODERN ARCHITECTURAL AESTHETICS**

Vladana Stanković, Goran Jovanović, Mirko Stanimirović 766

**INTEGRATED DESIGN OF STRUCTURAL SYSTEMS**

Aleksandra Nenadović 772

**NEW COMPOSITE SLAB SYSTEM – LIGHTWEIGHT CONCRETE, STEEL SHEETING AND REINFORCEMENT**

Zoran Šobić, Jelena Milošević, Miodrag Nestorović 780

**MODERN METHODS OF STRENGTHENING MASONRY WALLS**

Nenad Šekularac, Jasna Čikić Tovarović, Jelena Ivanović Šekularac 788

**NEW PERSPECTIVES FOR FERROCEMENT**

Ornela Lalaj, Yavuz Yardim, Salih Yilmaz 796

**Cultural patterns, Architecture and technologies**

<b>SPATIAL AND SOCIAL ASPECTS OF THE ARSENAL TRANSFORMATION, MILITARY PORT IN TIVAT INTO NAUTICAL – TOURISM SETTLEMENT AND PORT „PORTO MONTENEGRO“</b> Goran Radović	805
<b>DIGITAL FABRICATION IN THE FIELD OF ARCHITECTURE</b> Roberto Vdović, Morana Pap	816
<b>THE IMPACT OF SMART HOME TECHNOLOGIES ON ARCHITECTURAL DESIGN</b> Goran Petrović, Marko Aleksendrić	822
<b>BETWEEN THE PLACE AND NON-PLACE: ARCHITECTURE AND TERRITORY ON THE EXAMPLE OF SKOPJE</b> Saša Tasić, Mitko Hadzi Pulja, Minas Bakalchev	830
<b>INTEGRATED ARCHITECTURAL COMPLEXITY - FROM ABSTRACTION TO TECHNOLOGY AND MATERIALISATION</b> Rada Čahtarević, Dženana Bijedić, Amra Taso	838
<b>EVOLUTION DIGITIZED: ARCHITECTURE OF THE SUBLIME DREAM</b> Mihailo Popović, Vladimir Milenković	846
<b>MONOCHROMATIC IN THE ARCHITECTURAL COMPOSITION: WITH SPECIAL REFERENCE TO THE APPLICATION OF WHITE COLOUR</b> Dragana Vasiljevic Tomic, Rifat Alihodzic, Dragana Mojsilovic	853
<b>(RE)GENERATION &amp; REFLECTIONS OF THE SCHOOL OF ARCHITECTURE – BANJALUKA IN THE CENTURY OF KNOWLEDGE AND SKILLS</b> Milenko Stanković, Una Umićević	864
<b>QUANTUM ARCHITECTURE, NON-PLACE AND ACCULTURATION</b> Dubravko Aleksić	873
<b>PLACES AND PRACTICES OF CONSUMPTION IN THE POST-SOCIALIST CONTEXT</b> Dejana Nedučin, Dušan Ristić, Vladimir Kubet	880
<b>INTERACTIONS BETWEEN LIGHT AND ARCHITECTURE: AN EXPERIMENT USING MODELS AND PHOTOGRAPHS</b> Anita Stoilkov-Koneski	888
<b>THE INTERPLAY OF MUSIC AND ARCHITECTURE: LAYERING OF SOUND AND SPACE</b> Anja Kostanjšak, Morana Pap	895
<b>CULTURAL PATTERNS AND SENSITIVITY TODAY: FROM THE PHILOSOPHY TO THE TECHNOLOGY IN ARCHITECTURAL DESIGN PROCESS</b>	

Małgorzata Kądziela, Anna Sachse-Rynkowska	904
<b>PART III: PLACES, TECHNOLOGIES AND RELATED FIELDS</b>	
<b>Big data, apps, social networks and microblogs in urban planning and design</b>	
<b>PLACE COMPETITIVENESS EXPRESSED THROUGH DIGITAL DATA. MEASURING THE PLACE ATTRACTIVENESS TRACKING THE GEOTAG DATA VISUALS</b>	
Milena Vukmirovic, Eva Vanista Lazarevic	914
<b>ROOM BOOK 2.0 – BRING BACK THE INFORMATION TO ITS PLACE</b>	
Christoph Breser, Stefan Zedlacher	926
<b>THE INTERCONNECTED OBJECT: ARE YOU AT HOME IN A NETWORK?</b>	
Kalina Ntampiza, Polina Zioga	936
<b>THE INTERACTION TIME IN A NETWORKED SOCIETY</b>	
Danijel Baturina	944
<b>GOOGLE EARTH AS A MICROWORLD</b>	
Milena Zindović	962
<b>TRANSPARENCY OF SCALE: GEOGRAPHICAL INFORMATION PROGRAM (GOOGLE EARTH) AND THE VIEW FROM BEYOND</b>	
Pavle Stamenović, Dunja Predić, Davor Ereš	970
<b>Geodesy and modern cartography</b>	
<b>ROBUST ESTIMATION APPLIED TO GEODETIC DATUM TRANSFORMATION USING A METAHEURISTIC ALGORITHM</b>	
Mevlut Yetkin	979
<b>THE STATE OF THE ART SURVEYING BY TECHNOLOGY OF THE TERRESTRIAL LASER SCANNING</b>	
Marko Pejić, Branko Božić, Verica Erić, Jelena Pandžić	987
<b>ROLE OF CARTOGRAPHY IN MAKING A “SMART CITY”: CASE STUDY OF INDIJA</b>	
Dragutin Protić, Ivan Vučetić, Ivan Nestorov	995
<b>MODERN CARTOGRAPHY IN PROJECT OF CENSUS</b>	
Maja Kalinić, Dragoljub Sekulović	1002

## **Mobility and technologies**

### **PERSONAL RAPID TRANSIT – A SUSTAINABLE URBAN TRANSPORT SYSTEM**

Ljupko Šimunović, Luka Novačko, Mario Ćosić 1011

### **FLIGHTPATH TO AN ENVIRONMENTAL FRIENDLY AIR TRANSPORT**

Ivana Čavka, Olja Čokorilo, Slobodan Gvozdenović 1020

### **PRESERVATION OF PLACE-IDENTITY THROUGH URBAN TRANSFORMATIONS BASED ON SUSTAINABLE FORMS OF TRANSPORT**

Miloš Kopic 1029

### **BELGRADE RIVERSIDE TRAFIC INTERCHANGES**

Ksenija Stevanović, Milena Stevanović 1037

### **SUSTAINABLE URBAN MOBILITY PLANS IN EUROPE**

Davor Brčić, Ljupko Šimunović, Marko Slavulj 1045

### **URBAN DEVELOPMENT IN BELGRADE IN THE CONTEXT OF GLOBAL TRENDS: CHANCES OF ILLEGAL HOUSING INTEGRATION**

Biserka Mitrović, Miodrag Ralević, Branislav Antonić 1051

### **RE-THINKING INFRASTRUCTURE PROJECT FOR THE METROPOLIS: LABORATORY GRANADA**

Juan Luis Rivas Navarro, Belén Bravo Rodríguez 1059

## **Public participation, e-governing and tehcnology**

### **COMMUNITY PARTICIPATION AND GREEN INFRASTRUCTURES: A DELIBERATIVE EVALUATION METHOD**

Saverio Miccoli, Fabrizio Finucci, Rocco Murro 1067

### **RESULTS OF INTRODUCTION OF PARTICIPATORY TOOLS IN URBAN PLANNING IN SERBIA – 7 CASE STUDIES**

Ratka Čolić, Harald Mueller 1075

### **WAYS TOWARDS A CITY OF NEW TECHNOLOGIES**

Miodrag Ralevic, Tatjana Mrdjenovic, Natasa Krstic, Djemila Beganovic 1083

### **PARTICIPATION OF CITIZENS IN TOWN PLANNING PROCEDURES IN NEIGHBOURHOODS WITH FORMER REFUGEE AND DISPLACED POPULATION IN PRIJEDOR, BOSNIA AND HERZEGOVINA**

Rada Latinović 1090

### **THE ROLE OF INFORMATION AND COMMUNICATION TECHNOLOGY IN A VIRTUAL ORGANIZATION**

Jelena Lukić 1098



## INTEGRATED DESIGN OF STRUCTURAL SYSTEMS

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### ABSTRACT

*This paper deals with the concept of integrated structural design, within an integrated approach to the design and evaluation of buildings, for the purpose of achieving ecological quality of buildings, in line with recommendations for sustainable building development. Integrated structural design refers to reduction of negative environmental impact and resource consumption, with a simultaneous increase in life quality and health and safety in the built environment. Integrated structural design is based on targeted integrated performances of a building throughout its life cycle. This type of structural design is based on a systemic approach, in which the structure of the building is seen as a functional unit, i.e., as a sub-system of the building, whose behaviour is directed towards the aim of the system-building – ecological quality. In this process, a structure cannot be understood, and thus evaluated, without understanding its relationship with the specific function of architectural space. This systematic approach in its practical operationalization has the design of system-buildings of different relationships and connections among sub-systems, building structure and construction materials, that is, the design of buildings of various quantitative and qualitative properties, with a higher common property – ecological quality.*

*Keywords: sustainable building, ecological quality of buildings, integrated building design, integrated structural design*

### INTRODUCTION

Activities related to the buildings, in addition to affecting the quality of life and the economy, are most responsible for environmental damage (A. Nenadović i M. Nenadović, 2002). It is necessary to reduce the negative environmental impacts and resource consumption due to the construction, use and demolition of buildings, with a simultaneous increase in quality of life and health and safety in the built environment (Working Group for Sustainable Construction, 2001, 11). In order to achieve the stated aims, special attention should be paid to the design of buildings, since the "design is in the base of problem of the relationship of people and the environment and the changes in those relationships" (Blagojevic and Ćirović, 2011, 24), that is, up to "80% of a product, service or system's environmental cost is determined at the design stage" (Design Council, 2002, 10). Building design "based on the principles of sustainable development" (Law on Planning and Construction of

the Republic of Serbia, clause 3) implies an integrated approach (Working Group for Sustainable Construction, 2001, 13), based on the systemic analysis of social, economic and environmental aspects (Birkeland, 2002, 7). It is a holistic approach, based on targeted integrated performances of buildings throughout their life cycle, that is, on integration of project objectives, as well as the integral quality assessment of the designed solutions in accordance with the quantitative and qualitative indicators of ecological quality of buildings (Nenadović, 2014). This type of design involves research strategies that transcend disciplinary boundaries, in order to comprehend the relations between building subsystems, including the building structure and structural materials, as well as the behaviour of these sub-systems directed towards achieving the goal of the system-building – ecological quality. The result of this systemic approach, in its practical operationalization, is a conception of system-buildings of different relations between sub-systems, that is, conception of buildings of various quantitative and qualitative properties, with a higher common property – ecological quality.

#### ECOLOGICAL QUALITY OF BUILDINGS

The key theme within the integrated approach to building design is the establishment of multiple design sub-goals in function of achieving the main goal – ecological quality (Nenadović, 2014). When it comes to the design of building subsystems, including the design of building structure, building can be taken as the system boundary, that is, as the system which is attributable to ecological quality (Bell, and Morse, 2008, 12). Life cycle of a building is taken for the time frame during which the ecological quality of a building is assessed (European Committee for Standardization, 2011). Ecological quality can be interpreted as the „extent to which performances of the building meet the needs and expectations of its users, which refer to social and economic well-being achieved with simultaneous protection and improvement of the environment throughout the life cycle of the building” (Nenadović, 2014, 21), while its determination may be carried out according to the criteria and indicators for assessing the ecological quality of buildings (Nenadović, 2014). The subjects of the analysis are the effects on the global and local environment throughout the life cycle of the building. The objective is to reduce harmful emissions into air, water and land, as well as increase the efficiency of resource use (Commission of the European Communities, 2005, 5). It is also necessary to consider the extent to which performances of the building meet the needs<sup>190</sup> and expectations of its users during the use phase of the building. Two key aspects of quality of the architectural space should be considered during design: functional and symbolic (Giuliani and Feldman, 1993; Williams, Patterson, Roggenbuck, and Watson, 1992). These aspects concern the consideration of the conditions that should support the users' activities, that is, the possibilities of space to stimulate the desired experiences (Kyle, and Chick, 2007; Williams, Patterson, Roggenbuck, and Watson, 1992; Božović-Stamenović, 1997, 65-66). The objective is

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<sup>190</sup> These are fundamental human needs (Max-Neef, 1991, 32-33).

the realisation of architectural spaces that contribute to quality of human life, that is, well-being, through preservation and improvement of their health, and incitement of the sense of security, amenity and harmony with the living environment (Nenadović, 2014, 28). In addition, it is necessary to estimate the life cycle costs of the building<sup>191</sup>, as well as the ability to maintain the value of the building (Menger, 1871; Ćirović, Jovović i Luković, 2010), wherein it should be kept in mind that users are interested in buildings that can meet their needs to a greater extent, that is, to improve the quality of their activities, while simultaneously reducing operating and maintenance costs (Construction Task Force, 1998).

### INTEGRATED DESIGN OF STRUCTURAL SYSTEMS

Integrated building design, as a process that enables achievement of ecological quality, implies involvement of clients, contractors, construction professionals, end users, as well as early and intense involvement of all members of the design team, whose members make decisions together in accordance with a shared vision and a holistic understanding of the project (Ritchie, 1995; Busby Perkins + Will, and Stantec Consulting, 2007). Non-linear, iterative design process (Knudstrup, 2004) is based on multiple, often various forms of knowledge and processes (Moe, 2008, 6-7). In the process of integrated building design concepts are evaluated through the aggregation of fact and value judgments, in accordance with the quantitative and qualitative indicators of ecological quality (Nenadović, 2014). In this process, the decision-making becomes an art of finding the best compromise with the aim to optimize the performances of the building as a whole, rather than to optimize its individual components (A. Nenadović and M. Nenadović, 2004, 240). In the context of the above, in the process of integrated building design, design of building structure is based on targeted integrated building performances throughout its life cycle. Integrated structural design is a systemic approach, within which the building structure is designed as a functional unit, that is, as a subsystem of a building whose behaviour is directed towards the aim of system-building – ecological quality (Nenadović, 2014).

One of many examples of buildings conceived through the process of integrated design is PowerGen headquarters building (Figure 1), the project pioneered energy-efficiency in the office sector, which was designed by Bennetts Associates, who "achieve the high levels of sustainability" through "multi-disciplinary, investigative approach to design" (Bennetts Associates, n.d.). During the design, a strategy for reducing the energy required for heating, cooling and lighting of the space, based on the use of passive techniques, was applied. The choice of structural material was crucial. Reinforced concrete structure was intended to act as thermal mass which

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<sup>191</sup> Primarily, it is necessary to consider the possibility of reducing operating and maintenance costs, given that these costs constitute the largest part of the life cycle cost (Krstic and Marenjak, 2012). These costs are primarily affected by durability and reliability of the building, space adaptability, space utilization and energy efficiency of building, which are largely determined by the solution of a building structure (Nenadović, 2014).

contributes to the control of indoor climate by reducing the thermal leaps. Concrete floor structure is shaped in accordance with the requirements related to the proper acoustics, lighting and thermal performances of workspace (larger surface thermal absorption), and in accordance with the requirement of "elegant" (O'Neill, Shaw, and Flynn, 1996) and structurally efficient solution.



**Figure 1. Bennetts Associates, PowerGen headquarters building, Coventry, UK, 1994, construction, interior. [Source: O'Neill, B.T., Shaw, G., and Flynn, M. (1996). *Project Profile: PowerGen Headquarters*. British Cement Association; <http://www.bennettsassociates.com/portfolio/9109/>]**

Improvement of building performances in the context of sustainability, based on adequate materialization and shaping of building structure, was also achieved in Portcullis House (Figure 2), a project by Michael Hopkins and Partners, (today Hopkins Architects), and in Wessex Water Operations Centre (Figure 3), a project by Bennetts Associates. Proposed solution of the structure, which is, according to Peter Smith "one of the most aesthetically and environmentally suitable methods of achieving radiative thermal mass" (Smith 2005, 136), is derived from a philosophy that is based on "the integration, rather than the duplication of elements" and design approach that "synthesizes creative imagination and rational logic" (Hopkins Architects, n.d.). Structurally efficient, arched reinforced concrete floor structure<sup>192</sup> is exposed from the bottom surface, thus improving the effectiveness of thermal mass. In winter, the structure accumulates heat during the day and then radiates it to the internal space during the night. In summer, the cooler night air passes through the cavities and cools the plates, which then cool the space during the day, that is, reduce the temperature maximum<sup>193</sup>.

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<sup>192</sup> Thanks to the structurally efficient, vaulted floor structure, 50% less concrete than in the case of traditional flat reinforced concrete plate was embedded, which reduced embodied energy of a building.

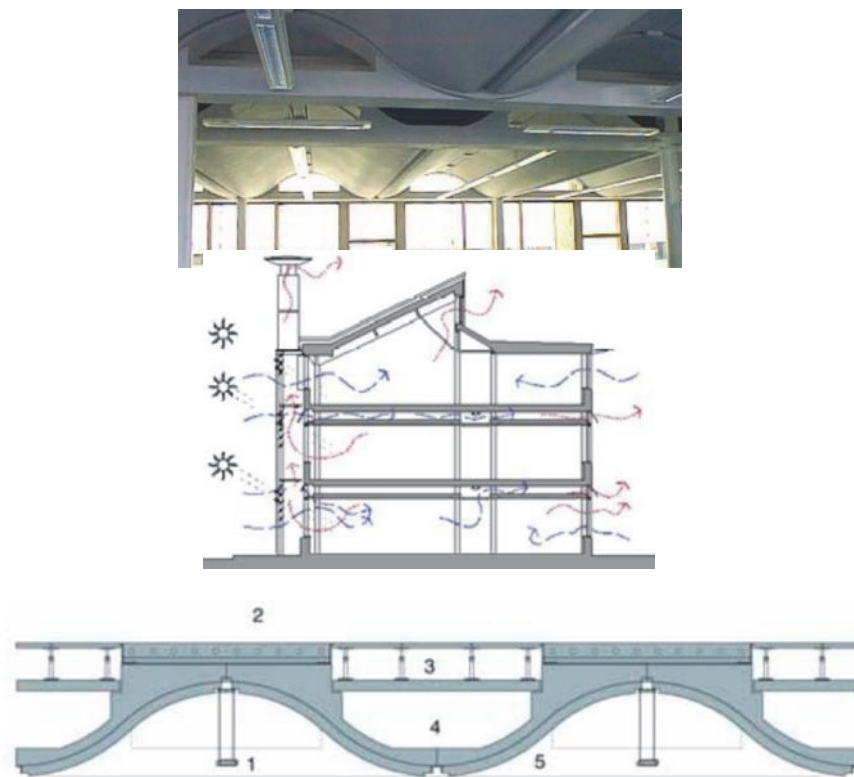
<sup>193</sup> The solution does not imply suspended ceiling, but raised floor within which the installations are distributed.



**Figures 2 and 3. Arched reinforced concrete floor structure in Portcullis House, London, UK, 2001, designed by Michael Hopkins and Partners and in Wessex Water Operations Centre, Bath, UK, 2000, designed by Bennetts Associates. [Sources: Smith, P. F. (2005). *Architecture In A Climate Of Change: A Guide to Sustainable Design*. Elsevier/Architectural Press. 137; <http://www.bennettsassociates.com/practice/sustainability/>]**

In office building of Building Research Establishment organisation, a project by Feilden Clegg Bradley Studios which promotes social and environmental sustainability and which pursues research-led design, vaulted reinforced concrete floor structure (Figure 4) is holistically designed in order to satisfy multiple functions. Load bearing floor structure, i.e., vaulted slabs and specially shaped beams, are initially shaped according to the requirement for effective air paths through the building, within the system of natural ventilation of indoor building spaces which should ensure air comfort for users. The shape of the slabs and beams allows a deeper penetration of daylight and thus greater light comfort. The design team used the mass of the exposed concrete shells, in conjunction with active and passive strategies for heating and cooling, in order to control the temperature changes in the indoor environment<sup>194</sup>. With sinusoidal profile of the floor structure the surface of the ceiling is maximised, in function of the more effective modification of interior space temperature. Cooling of indoor space during the summer is achieved by night ventilation. During the night, in addition to ventilation through windows, air is retracted directly into the floor structure channels, thus providing its additional cooling. Cooling the indoor space in summer is further improved by circulation of cold water through pipes embedded in the floor slab. During the winter, minimal amount of air needed for the ventilation of indoor spaces runs through floor structure channels. The air is heated this way, thus reducing the need for heating. During the winter, heated water runs through pipes embedded in the floor slabs (Harrison, 2006, 3).

<sup>194</sup> New European directive changes the approach to evaluation of the energy performances of buildings, within which attention is given to the internal elements of the building, including the building structure, in addition to the building facade and the question of its tightness (Directive 2010/31/EU, 2010). The importance of passive techniques in context of heating and cooling is emphasized.



1- luminaires, 2 – layer with embedded system for heating and cooling, 3- raised floor, 4 –ventilation channel, 5- prefabricated vaulted concrete shell with a layer of concrete poured on site

**Figure 4. Feilden Clegg Bradley Studios, building of BRE organisation, Garston, UK, 1996, interior, ventilation strategy illustrated in cross-section, cross-section through sinusoidal floor structure [Sources: Harrison, C. (2006). *The Environmental Building, The Building Research Establishment (BRE) Office Building. Case Study; Feilden Clegg Architects*]**

The above examples of office buildings point to possibilities that open through application of the methodological concept of integrated, multidisciplinary, research-led design, which is based on thinking outside of the standard solutions. They also point to importance of this new approach to design, especially having in mind the attitude according to which architecture allows us to influence social change and respond positively to the environmental crisis (Feilden Clegg Bradley Studios, n.d.).

## CONCLUSION

This paper points to new aspects of structural design within an integrated approach to building design, as well as to the complexity and plurality of answers in the area of structural engineering directed towards the achievement of the ecological quality of buildings. In view of the complex nature of the integrated design of buildings

which assumes the study of problems of the system - building from the standpoint of different interrelated disciplines and research strategy that transcends disciplinary boundaries, it is necessary, above all, to explore new models of education of designers involved in the design of buildings, in order to prepare them for multidisciplinary optimization of design solutions based on multiple analysis of many aspects of ecological quality, in function of effective application of this methodological concept in design practice.

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