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Articles and Statements

Ecological Factors Regarding to the Site Selection and Architectural Design of Parking Garages

Bujar Bajçinovci [a, *]

[a] University of Prishtina, Faculty of Civil Engineering and Architecture, Kosovo

Abstract

In the process of spatial planning there are the inevitable urban zones with the commercial public buildings, as one of the segments of the overall development of the city. They represent certain mandatory fulfilment for the functional urban design categories. However, actually, what happens to the environment? Urban actions should be preserved and limited in terms of the environmental impact. The aim and objective of this paper is to address dimensions that relate to the parking garages in relation to air quality, and health impact according to the actual site location and distance of open public parking garage to the communities. The research methods consist of empirical observation through urban zones of Prishtina, with an accent to the future structures of the parking garages in the city. Hence, the same architectural design strategy cannot respond to all specific problems faced by contemporary urban issues. The current degraded state of environment as a whole "Umwelt", requires specific responsibilities and activities, exclusively when the environmental condition is directly linked to the quality of life and public health. Based on the conceptual results of air pollution and ecological concepts for parking garages presented in this paper, site locations for the parking garages of Prishtina must fundamentally accompany ecological patterns for the healthier communities in coming decades.

Keywords: architecture, ecology, design, parking garages, environment.

1. Introduction

In the process of spatial planning there are the inevitable urban zones with the commercial public buildings, as one of the segments of the overall development of the city, they represent certain mandatory fulfilment for the functional urban design categories. However, what happens to the environment? Urban actions should be preserved and limited in terms of environmental impact. Decisions for actions of this nature in connection with the community and contemporary society needs are more complex and present a wide functional system, with full comprehensive nature. Hence, we must seriously respect the ecological procedures for obtaining the legal opinion of all stakeholders in the process. Moreover, the 'green' strategies regarding to the preservation of the environment often show greater activities in relation to financial boards or comities and decision-makers, therefore, we must encourage to actively participate on public debates for these

* Corresponding author
E-mail addresses: bujar.bajcinovci@uni-pr.edu (B. Bajçinovci)

vital final decisions. Furthermore, in relation to communities which are near those polluted zones or specific architectural structures which emanate or contribute to air pollution, surely we must undertake environment protection actions to all the specific tasks and requirements in terms of capacity, planning, development, traffic, volume of use, the risk of environmental pollution and noise pollution.

"Many structures cope with fundamental demand of functional, energy efficiency and sustainability objectives, with the immediate need to implement the energy of new renewable sources … Hence, we aim environmentally and sustainable to introduce those actions into the practice, green actions, backed up with the legal premise for environmental protection and respect the biodiversity" (Bajçinovci, 2016).

Parking garages are major infrastructure facilities in the complex parking urban zones, which may be located above or below ground. Parking garages are also important contributing sources of air pollution, with environmental impact near or beyond of their site location. But at the same time, they are also functional auxiliary points accompanied to the cultural, social, economic and commercial architectural structures. Parking garages with a quality architectural design play a symbiosis with other buildings features, which in many cases shape the state of operating environment system as an urban entity in itself.

There is a huge traffic of potential urbanites in between urban zones, and urban regional communities, accompanied with different types of functional services such as hotels, airports, and mega terminal structures, a complex situation where essentially the architects and urbanists has a crucial role to address the conceptual models of urban planning (Bajçinovci, 2016).

Among the negative impacts on the surrounding environment, the dominant position of functional architectural complex is a source of environmental pollution causing noise and air pollution in their surroundings as well as the emission of significant quantities of harmful gases. Noise from vehicles is one of the most difficult problems to be addressed. These emissions reach peak operations during and about inadequate parking (operating, manoeuvring, igniting, obtaining and driving force behind), furthermore, the noisier actions are, the dominant long narrow parking manoeuvres. Moreover, the problem of noise is one of the problems which is constantly being addressed by the UN and WHO, to the date. Basically, there are five approaches to mitigate the noise problem as follows:

- Site selection, and optimal use of the location and environment for parking garages.
- Adequate urban planning, with communities near the parking garage facilities, with sound insulation barriers.
- The use of Nano materials and contemporary technology in architectural building structures in relation to preserve the environment
- Implementing the new contemporary technologies related to the gas emissions from vehicles and heavy traffic.
- The full environmental policy functionality of parking garages in the context of procedures for sustainable operation.

Hence, the determination of design strategy requires many factors to be considered in selecting the best access and management options with project delivery methods suitable for preserving the environment and public health. All motor combustion engine vehicles during their operation create noise pollution, especially in a heavy traffic urban zones and dense populated communities, a pollution, which present a permanent environmental issue. Problem arise, when vehicles are operating close to the residential areas and urban areas, in actions to make parking operations, goods handling, preparation and departure procedures. It can be conceptually concluded that all cities in the world are more or less affected by air pollution. Therefore, ecological factors regarding to the site selections and architectural design process of parking garages are crucial and fundamentally necessary, for healthier communities and requires the consent of local neighbourhood.

2. Material and Methods

There are an essential and vital questions: which are the biggest pollutants emitted in parking garage structures and their level of toxicity? To answer those questions, we must investigate the problem locally in a very complex research methods. Therefore, we must consider the risks associated with any contaminants, risk includes emanation of pollutants but also we must consider in account their exposure in time, in relation to the toxicity. Regarding to the level of the toxicity that causes damage to health, special attention should be taken in a pollutant that can be emitted in small amounts, however, they represent significant risk. In contrast, focusing on pollutants with high overall emissions (across the garage) can be treated with a less attention on toxic pollutants relatively which may emanate, thus, in preliminary analysis of the emanations are minor quantities without having an impact on public health. However, the component of time dimension and route of exposure to them, should be taken into account, presented in Figure 1.

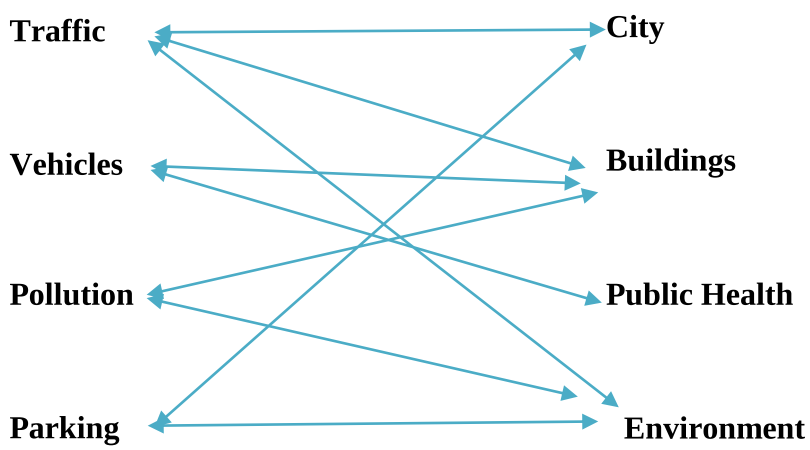


Fig. 1. Ecological interdependence of urban design factors

Many parking garages are islands of high level pollution, air quality is significantly poorer than in urban surroundings, poor quality of air adversely affects the health of humans and other species that exist or may be transported in the vicinity of the neighbourhood. Those ecological phenomena are especially visible and may lack the quantities of vegetation, trees and shrubs along the traffic roads to the parking garage. Poor air quality in open space conceptually means that the buildings suffer from poor quality of indoor air. Consequently, the closed types of parking garages are maintained with air conditioning, either in whole or in part zones, by adding at least indirectly health problems through the use of CFCs. Therefore, the right sustainable development necessarily affects the neighbourhood, site location, architectural design approach of parking garages, and land use planning.

"Outdoor concentrations of traffic-related air pollutants (nitrogen dioxide $PM_{2.5}$, particles with a 50 % cut-off aerodynamic diameter of 2.5 mm and soot) were assigned to birthplace home addresses with a land-use regression model […] Traffic-related pollution was associated with respiratory infections and some measures of asthma and allergy during the first 4 yrs. of life." (Brauer, 2007; Bajçinovci, 2016).

Also, in Kosovo, there was study research in the field of air pollution and efficiency of energy, related in emissions of CO_2 and Gross Domestic Product, "Kosovo as one of the richest countries with lignite in Europe with 95–97 % of the electric power production from lignite and with 90 % of vehicles over 10 years old, represents one of the regions with the greatest CO_2 output per GDP per unit of economic activity, as well as one of the countries with the most polluted atmosphere in Europe. In this relation, we must consider the fact that Kosovo is a developing country (Kabashi, 2011; Bajçinovci, 2016). Besides the use of energy, commercial buildings and parking garages are big users of other resources and land resources. As a result of this consumption, buildings are significant producers of waste volumes, pollution (air, water, noise) and land pollution in the long-term cycle of heavy metals.

The contribution of parking garages on air pollution can be tricky, because of all those pollution factors can influence significantly to the pollution of the site. Also, many of them can contribute in different ways and react dramatically in interdependence with each other (one factor may interfere with the effectiveness of another). Therefore, parking garages can generate lower emissions of certain pollutants, such as nitrogen oxides (NOx), but because the surrounding environment it may be affected by weather conditions or a climate that is conducive to forming the pollution, can contribute more to the detriment of air quality than a factory that produces higher emissions of NOx. The situation becomes more complicated when health hazard effects are being generated, as this depends on the location of the community. The research case is made, when the community surrounding is in vicinity of parking garage, and it is directly affected by prevailing dominant wind, then, this phenomenon causes the parking garage to be the biggest contributor which emanate environment pollution, and ecological hazard impact to the public health, presented in Figure 2.

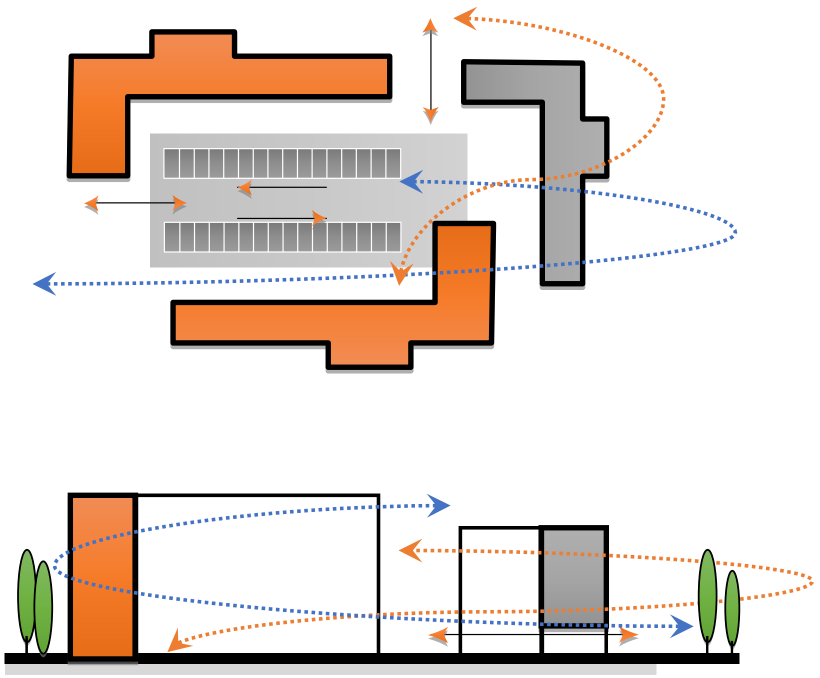


Fig. 2. Urban block zone, design of parking garages and effects of prevailing dominant wind in the neighbourhood

Primary and secondary pollutants refer to the pollutants that are emitted directly from a source (NOx, CO, VOCs, $PM_{2.5}$) or formed in the atmosphere through chemical reactions or physical processes with secondary pollutants. The main pollutants in parking garages and similar buildings:

- Carbon monoxide (CO)
- Nitrogen dioxide (NO_2)
- The particles are 10 µm in diameter (PM_{10})
- The particles are 2.5 µm in diameter ($PM_{2.5}$)
- Sulphur dioxide (SO_2)

Similarly, international standards set a dangerous pollutant emissions to the air, necessary to control the mass air toxics emissions by promoting technology-based standards for each type of buildings separately, also, objectives targeting the exposure of the population and air quality standards as presented in Table 1 and Table 2.

These standards apply to equipment used in buildings, such as: power generators, boilers. “Humans can be adversely affected by exposure to air pollutants in ambient air. In response, the European Union has developed an extensive body of legislation which establishes health based standards and objectives for a number of pollutants in air. These standards and objectives are summarised in the table below. These apply over differing periods of time because the observed health impacts associated with the various pollutants occur over different exposure times” (European Commission...).

Table 1. $PM_{2.5}$ objectives targeting the exposure of the population to fine particles, European Commission, (AEI). (European Commission...)

TITLE	METRIC	AVERAGING PERIOD	LEGAL NATURE	PERMITTED EXCEEDENCES EACH YEAR
PM2.5 Exposure concentration obligation	20 µg/m3 (AEI)	Based on 3 year average	Legally binding in 2015 (years 2013,2014,2015)	n/a
PM2.5 Exposure reduction target	Percentage reduction + all measures to reach 18 µg/m3 (AEI)	Based on 3 year average	Reduction to be attained where possible in 2020, determined on the basis of the value of exposure indicator, in 2010	n/a

Table 2. Air quality standards and objectives. (European Commission...)

POLLUTANT	CONCENTRATION	AVERAGING PERIOD	LEGAL NATURE	PERMITTED EXCEEDENCES EACH YEAR
Fine particles ($PM_{2.5}$)	25 µg/m3	1 year	Target value entered into force 1.1.2010 Limit value enters into force 1.1.2015	n/a
Sulphur dioxide (SO2)	350 µg/m3	1 hour	Limit value entered into force 1.1.2005	24
	125 µg/m3	24 hours	Limit value entered into force 1.1.2005	3
Nitrogen dioxide (NO2)	200 µg/m3	1 hour	Limit value entered into force 1.1.2010	18
	40 µg/m3	1 year	Limit value entered into force 1.1.2010	n/a
PM_{10}	50 µg/m3	24 hours	Limit value entered into force 1.1.2005	35
	40 µg/m3	1 year	Limit value entered into force 1.1.2005	n/a
Lead (Pb)	0.5 µg/m3	1 year	Limit value entered into force 1.1.2005 (or 1.1.2010 in the immediate vicinity of specific, notified industrial sources; and a 1.0 µg/m3 limit value applied from 1.1.2005 to 31.12.2009)	n/a
Carbon monoxide (CO)	10 mg/m3	Maximum daily 8 hour mean	Limit value entered into force 1.1.2005	n/a

Benzene	5 µg/m3	1 year	Limit value entered into force 1.1.2010	n/a
Ozone	120 µg/m3	Maximum daily 8 hour mean	Target value entered into force 1.1.2010	25 days averaged over 3 years
Arsenic (As)	6 ng/m3	1 year	Target value enters into force 31.12.2012	n/a
Cadmium (Cd)	5 ng/m3	1 year	Target value enters into force 31.12.2012	n/a
Nickel (Ni)	20 ng/m3	1 year	Target value enters into force 31.12.2012	n/a

Parking phenomenon represents and is a major urban problem, so therefore it is logical to conclude that certain types and forms of parking are extremely irrational. Regardless, all forms of traffic transport are in the inevitable need for areas designated for parking and parking garages. These urban areas are in a large scale of zones and usually provided in relation to the number of urbanites, workers, industry, and overall urban zone development. In most developed countries, the ratio between residential zones or parking garage, are in range from 1/3 to 1/2 of the residential area!

Fig. 3. Travel distance of vehicles, from point A to the B

To travel the distance from point A to point B, presented in Figure 3, passenger usually has many options available, ranging from urban buses, taxis, metro, trams, train, private automobile. In urban design planning, we must constantly use several enabled alternatives, in this research case if the passenger has several possibilities to go from point A to point B, then we can conceptually conclude, that urban design has sense of duty of functionality and vitality of society.

Therefore, the concept of right planning can affect the user to make a choice of means for transport, so that traffic in the city has to work as planned environmentally. In any circumstances the quantity volumes of vehicles are fully equal ecological pattern in the process of planning and urban design. The parking 'break' or 'rest' of vehicle occurs at the two fundamental points of any journey, which reflect two different geographical points and different periods of time! What happens at the starting point and to the final destination point? The vehicles need to 'rest' before departure and requires 'space', never less the vehicle should be left somewhere, where and how are the most crucial ecological question?

3. Discussion

The aim and objective of this paper is to address two dimensions that relate to the parking garages in relation to air quality, and health impact according to the actual site location and distance of open public parking garage to the communities in vicinity:

- Improving the quality of the urban environment and land use.
- The need for parking spaces and public parking garages in Prishtina.

The research methods consist of empirical observation through urban zones of Prishtina, with an accent to the future structures of the parking garages at the future urban design planning. In order to receive a clearer information's, research is made within spatial regulation of urban blocks, architectural structures, focusing on the ecological features regarding to the morphology of the city of Prishtina, environmental pollution, and quality of public health. This research was investigated through literature review, and urban city documentations.

From the data provided by the relevant offices, in 2014, in Kosovo were a total of 286,505 vehicles registered. Of them, only 111,855 are produced from 2000 and onwards, the others, or 61 % of vehicles are produced between 1942-1999. In general, it appears that the average age of the registered vehicles in 2014 was 18.1 years (GAP Institute, 2016).

According to the researched results it can be concluded that Prishtina is heavy polluted in relation to the suspended fine particles PM_{10} and $PM_{2.5}$. Moreover, Prishtina is heavily polluted due to its urban spatial position regarding to the major polluters, power plants Kosovo-A and Kosovo-B. At the same time, pollution is substantial supported by heavy traffic, accompanied by the prevailing winds which increase and distribute more this pollution in certain directions at the winter season (Bajçinovci, 2016).

Regarding to the wind direction and near distance of parking garages it is expected that air pollution have to affect more communities in the vicinity of zone. According to the study "the number of high-traffic roads within a 250 m' radius of a location, the presence of a major road within a distance of 50 m, the density of buildings within a 300-m radius and an indicator for the region of the country were used in the model [...] The finding of a positive association between air pollution and objectively measured sensitization to common allergens, supports the findings of subjectively reported symptoms" (Brauer, 2007; Bajçinovci, 2016).

Depending on the urban planning, architectural design, ecology, environment, technical and operating characteristics we can find four main groups of parking:

- Parking in residential area
- Parking at work
- Parking of vehicles for general purposes
- Parking areas and for special purposes

Parking in the residential area, an integral part of the residential zones, presented in Figure 4. Hence, construction of new residential areas, especially actually in Pristina, the most vital problem would be to provide parking spaces. Also, the parking zones must legally identify itself, who is the owner and maintainer of public spaces in the residential areas. Furthermore, parking problem becomes very pronounced in areas with high population density, respectively in cases, where > 300-350 inhabitants/ha.

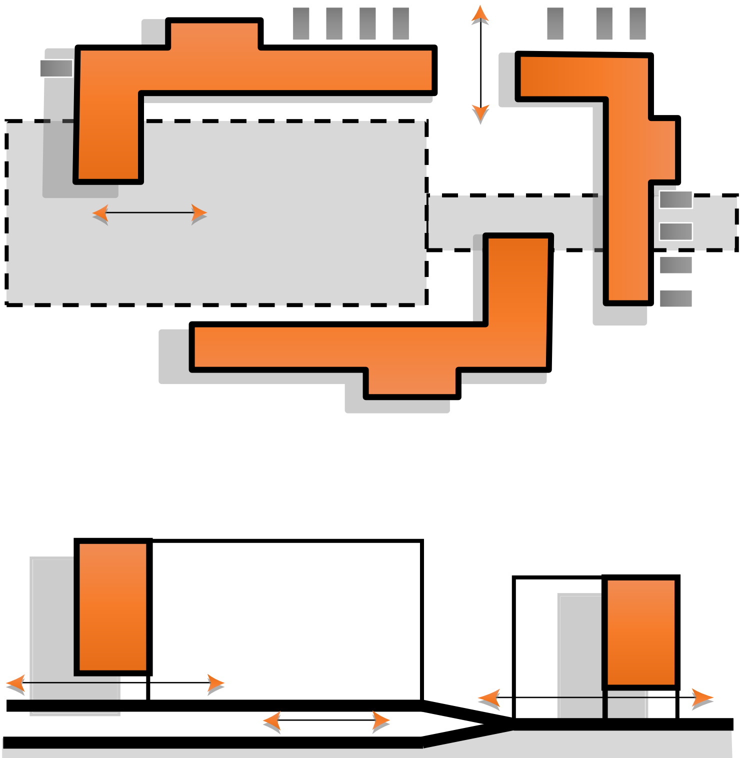


Fig. 4. Varieties of parking spaces in the residential areas

Parking in the workplace presented in Figure 5, this kind of typology are planned and will be constructed near commercial buildings with large concentration of workplaces, such as industrial complexes, administrative complexes, hospitals and similar buildings in Prishtina. Characteristic of this typology is that, those areas do not have a parking lot entrance and exit, parking zones as they are actually! It may happen that these parking areas are not near directly to the workplaces. Also, these parking areas may be at a distance with a greater travel destination, hence, it often happens that these areas for parking, are in the central area of the city and in different parts of the city that actually have good service of urban traffic. Moreover, these large areas of parking lots are often not rational as per urban design planning, and further complicate the situation by the high prices and the monthly costs reflecting to the family budget.

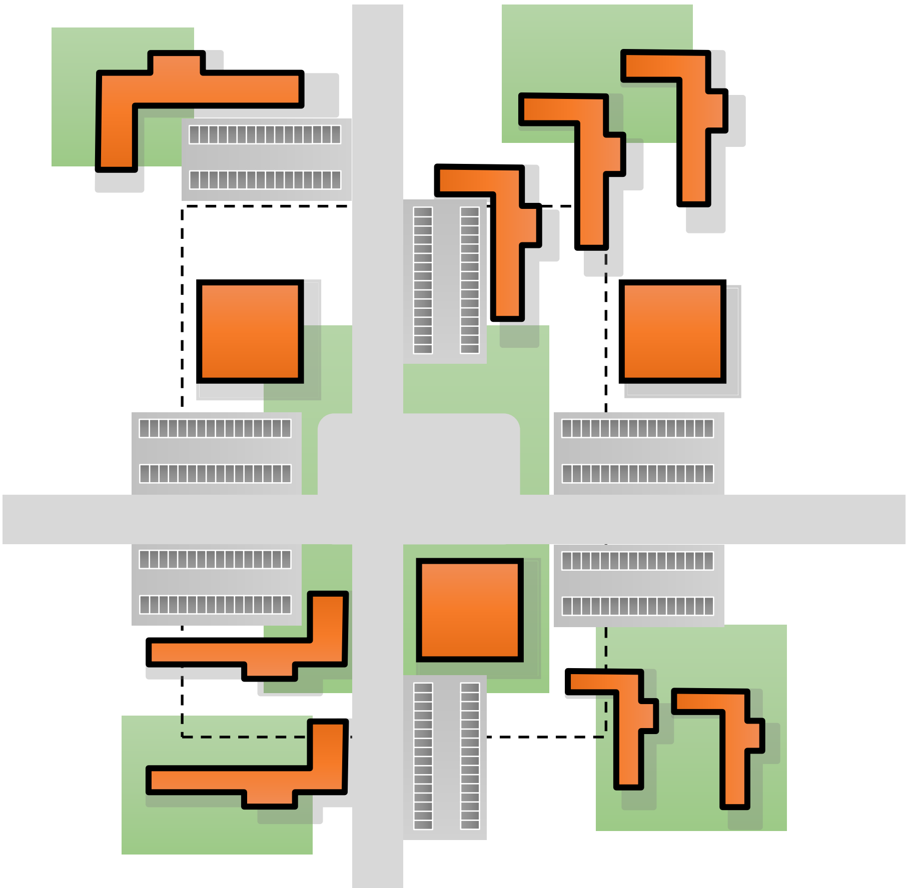
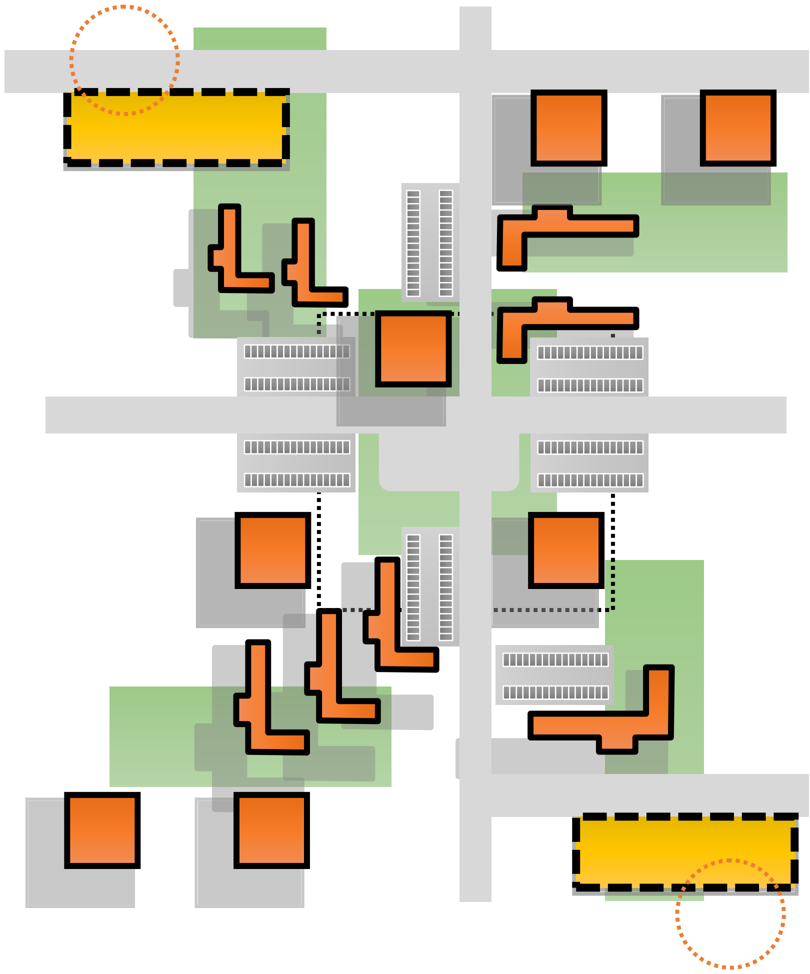


Fig. 5. Design of parking zones in the workplace areas



Parking zones as per general purpose, parking of vehicles for the purposes of general needs or public parking lots are planned near urban attractive general functions such as: shopping malls, architectural complexes of trade, business, entertainment, and sports activities, presented in Figure 6. Due to the attractiveness of the buildings they serve, these parking lots mainly are planned as heavy concentration parking zones, which are carried in the multi-storey buildings, as underground or above ground architectural structures, moreover, as buildings around the perimeter of the core of the city centre. By lately ecological standards those types of buildings should be subject to payment of ecological pollution compensation and compensation for negative impacts on urban space and public health.

4. Conclusion

Ecological specific problems of the time, we have to identify and to solve them in a more ecological and sustainable way, a heritage, which will not present a major problem for future generations. Global environmental challenges and air pollution is a global issue, hence, can't be addressed only locally. The same architectural design strategy cannot respond to all specific problems faced by contemporary urban issues. The current degraded state of environment and degraded ecology system as a whole "Umwelt", requires specific responsibilities and activities, exclusively when the environmental condition is directly linked to the quality of life and public health. Based on the conceptual results of air pollution, parking garages, and ecological concepts presented in this paper, site locations for the parking garages of Prishtina must fundamentally accompany ecological patterns for the healthier communities in coming decades. The potential future research will be more focused on the environmentally processes of the ecological patterns designs as an architecture sustainable strategy.

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Aloft Metabolism: A Juncture of Architecture Future Design

Bard Bajçinovci [a] , Uliks Bajçinovci [a] , Bujar Bajçinovci [b] , *

[a] "UBT" College, Faculty of Architecture, Prishtina, Kosovo
[b] University of Prishtina, "UP", Faculty of Civil Engineering and Architecture, Kosovo

Abstract

The Metabolism architectural concept, with its fundamental architectural and urban ideas has attracted the attention of wide architectural communities to Japan art development in the 1960-1970s. Nowadays, in 2010 more than half population live in modern cities, and by 2050, 7 out of every 10 people will live in urban areas. The study presented in this paper, has conceptually researched: architecture metabolism design models of future cities with its proportions and design concepts, mainly focussing on urban form and functional structures. This research, applied an empirical method through the arranged and combined structural models, furthermore, strengthened with handmade models in architectural studio as a research comparable volumes. The models were investigated thru comparative method, and researched mainly through literature review, especially studying structural interrelations of the: forms, position, proportions, and volume transformations thru time intervals. Global and wide actions are irreplaceable and crucially necessary to maintain the public health conditions in appropriate scale of modern cities. The current state of cities, requires specific municipal's responsibilities in situations when we are facing potentially hazards of public health. According to the conceptual conclusions of this study, we much prefer spatial patterns where the urban zones are more concentrated with high-rise structures, although preserving the land use for vegetation. Hence, we further argue that in 'verticality' the high-rise structures can be considered and environmentally treated as vertical farm 'green' mega cities. Urban planning issues, regarding to the: air pollution, climate changes, and public health hazards, fundamentally requires a holistic integrated environmental action. Global measures, as an environmental healing strategies!

Keywords: metabolism, architecture, urban planning, ecology, modelling.

1. Introduction

The Metabolism architectural concept, with its fundamental architectural and urban ideas has attracted the attention of wide architectural communities to Japan art development in the 1960-1970s. The first sense of the meaning of the word was a concept of renewal, the old with the new, hence, the members of the group explained this to be comparable to the extended awakening of the architecture, an organic growth of the modern cities (Lin, 2010). According to the World Health Organization; "in 1990, fewer than 4 in 10 of the world's population lived in cities. In 2010, more than half live-in cities, and by 2050, 7 out of every 10 people will live in urban areas" (WHO, 2010). Moreover, this rate of progression mostly is occurring in developing countries, as we

* Corresponding author
E-mail addresses: bujar.bajcinovci@uni-pr.edu (B.Q. Bajçinovci)

witnessed in Kosovo, where city infrastructure was overwhelmed by the rapid population boom in the beginning of the new millennium. Hence, "Cities are complex ecosystems with specific phenomenon directly reflected in our health, natural resources, economic, social and aesthetic fields. They are open integrated systems and huge organisms with specific and complex metabolism that transform vast amount of energy, generate huge amount of waste and emanate a number of specific environmental phenomenon and activities" (Bajçinovci and Jerliu, 2016). The systems to support the fast-growing cities have developed complex infrastructures and spatial activities, resulting with enormous investments and huge urban morphological actions. As stated by Pincetl, 2012: "While on a daily basis most of this has become part of daily life, normalized even, this complex set of physical and human social supply networks is fundamental to the functioning of society and cities; it is also insufficiently examined" (Pincetl, 2012). Cities in recent decades endure a considerable lack of space for much needed urban and spatial development, accompanied with extensive and complex social issues (Bajçinovci et al., 2016). Furthermore, cities are open integrated structures and wide entities with specific and aloft metabolism that transform enormous amount of energy, generate huge amount of waste and originate a sum of distinct environmental circumstances, and urban oscillations (Bajçinovci and Jerliu, 2016). Urban planning is a design process with a primary course to protect the environment, to manage urban infrastructure as a whole integrated system, and deliver the most appropriate style for living. In relation to sustainability and ecology, a qualitative urban design can significantly improve condition, and quality of life of citizens. Therefore, it is crucial to encourage every action, related to city functionality which will minimize any faced functional, and ecological issue. With a new millennium began a new epoch, a globalisation era, which will present a totally contrast and new living habits in the coming decades (Bajçinovci and Jerliu, 2016; Bajçinovci et al., 2016).

2. Materials and Methods

The study presented in this paper, has conceptually researched, an architecture metabolism design model of future cities with its proportions and design concepts, mainly focussing on urban form and functional structures. This research applied an empirical method through the arranged and combined structural models, furthermore strengthened with handmade models in architectural studio. The models were investigated thru comparative method, and researched mainly through literature review. Art and volumes studies contain handmade drawings of conceptual urban compositions, with the multi structural parts of the studied designs, especially studying structural interrelations of the forms, position, proportions, and constructive abilities of urban structures. Study is visually strengthened with the interrelation of art, architecture, and volume transformations thru time intervals (Bajçinovci and Jerliu, 2016), (Bajçinovci, Thaçi and Bajçinovci, 2016).

"Around the world, modern cities are centres of economic activity. Their skyscrapers and bustling marketplaces are testament to the development they have driven. Overall, urbanization has brought countries opportunity, prosperity and health" (WHO, 2010).

Furthermore, as presented by the joint UN-HABITAT/WHO report: "Modern cities are filled with shadows. Beneath the skyscrapers, behind the marketplaces, the lives of city dwellers are hidden from view. This is especially true for the urban poor living in slums or other informal settlements, which are often excluded from estimates of cities "economic and health development" (WHO, 2010).

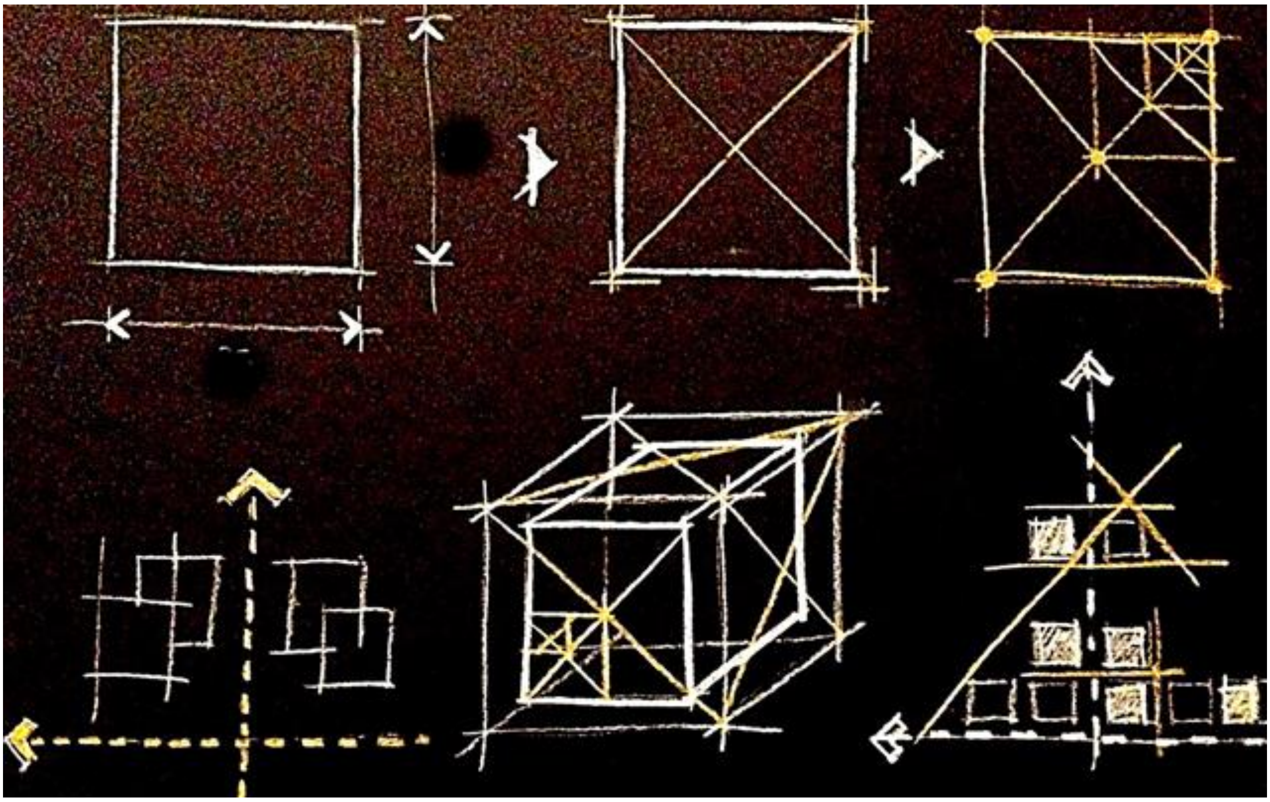

Fig. 1. Conceptual drawings, a simple square and cube. Holistic approach - the much more of the sum of all parts

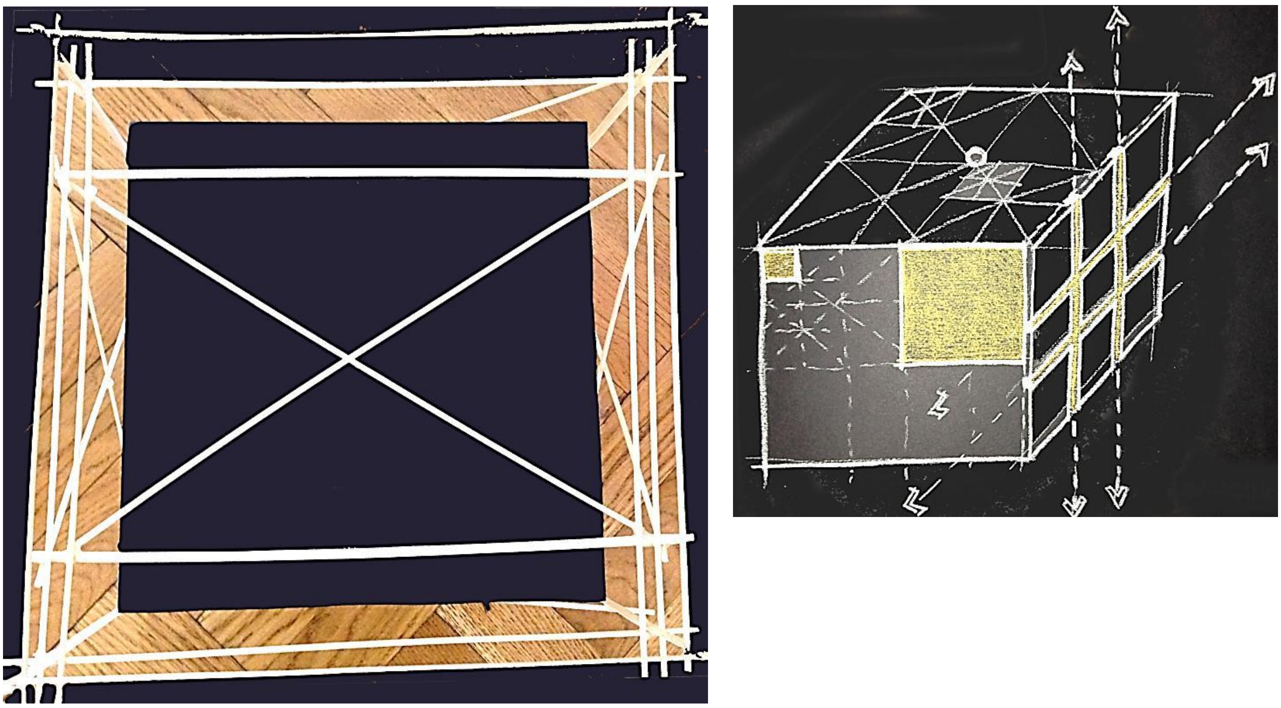

Fig. 2. Chosen cube model, multiplied unit for the high-rise structures. Contemporary architecture design unit for aloft metabolism

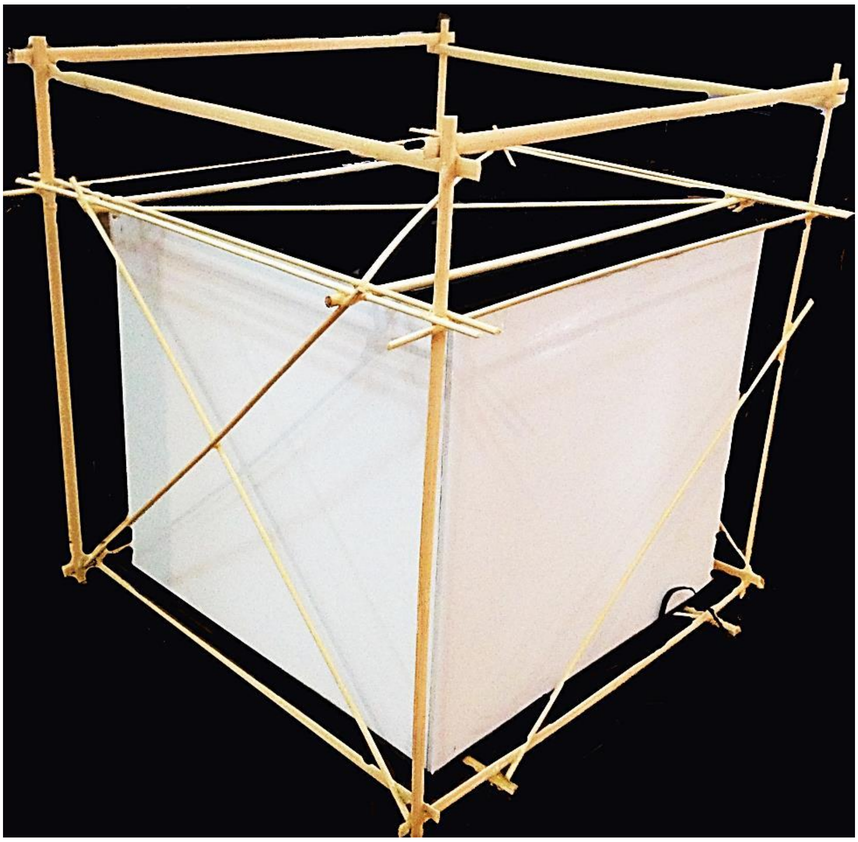

Fig. 3. 3D cube model, architectural multi-functional unit for the high-rise structures

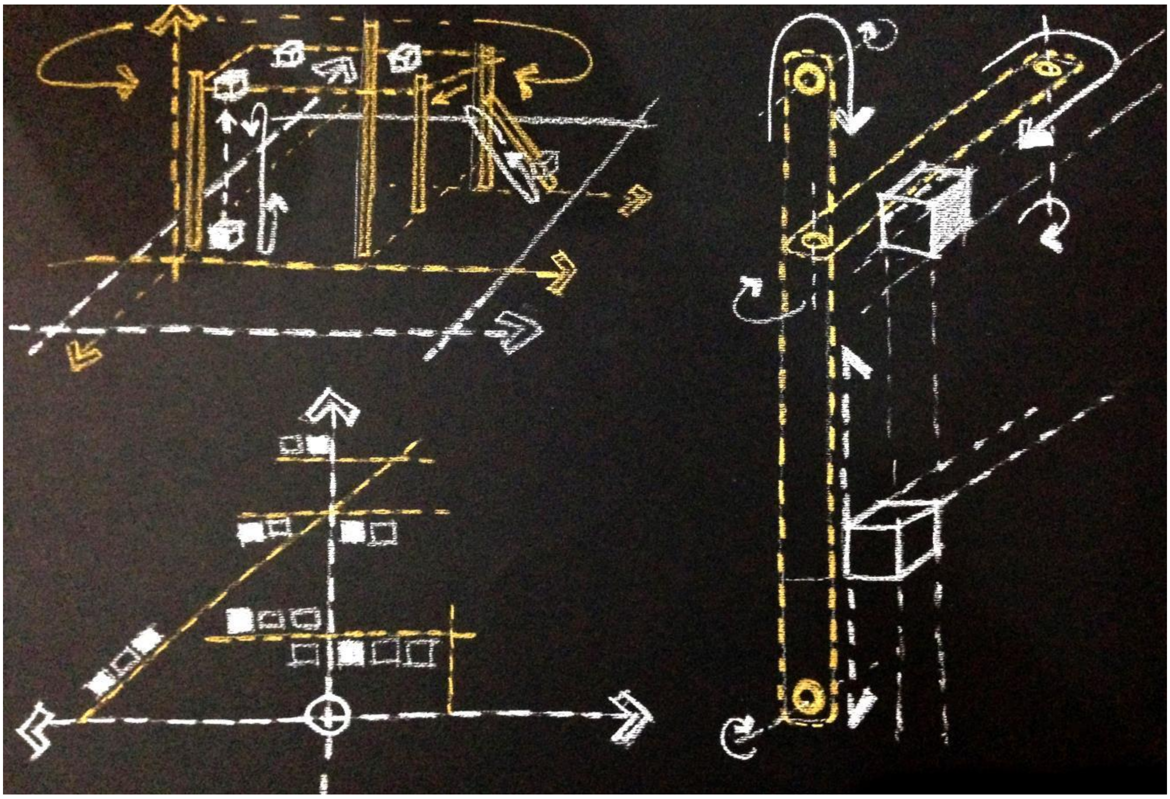

Fig. 4. Conceptual drawings, a schematic line movement of structural units. Juncture of time and space intervals, forming the wholeness of the architectural structures

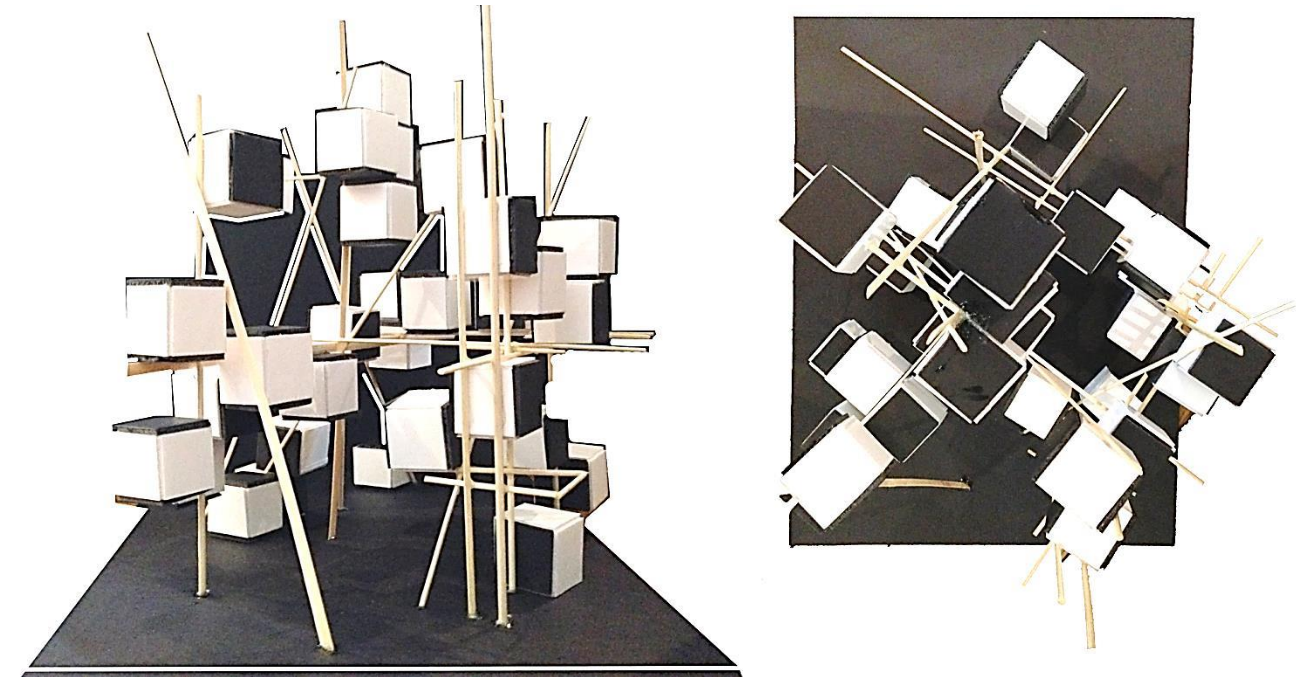

Fig. 5. 3D space, formed aloft architecture metabolism structures. Contemporary architecture reflection of modern mega cities.

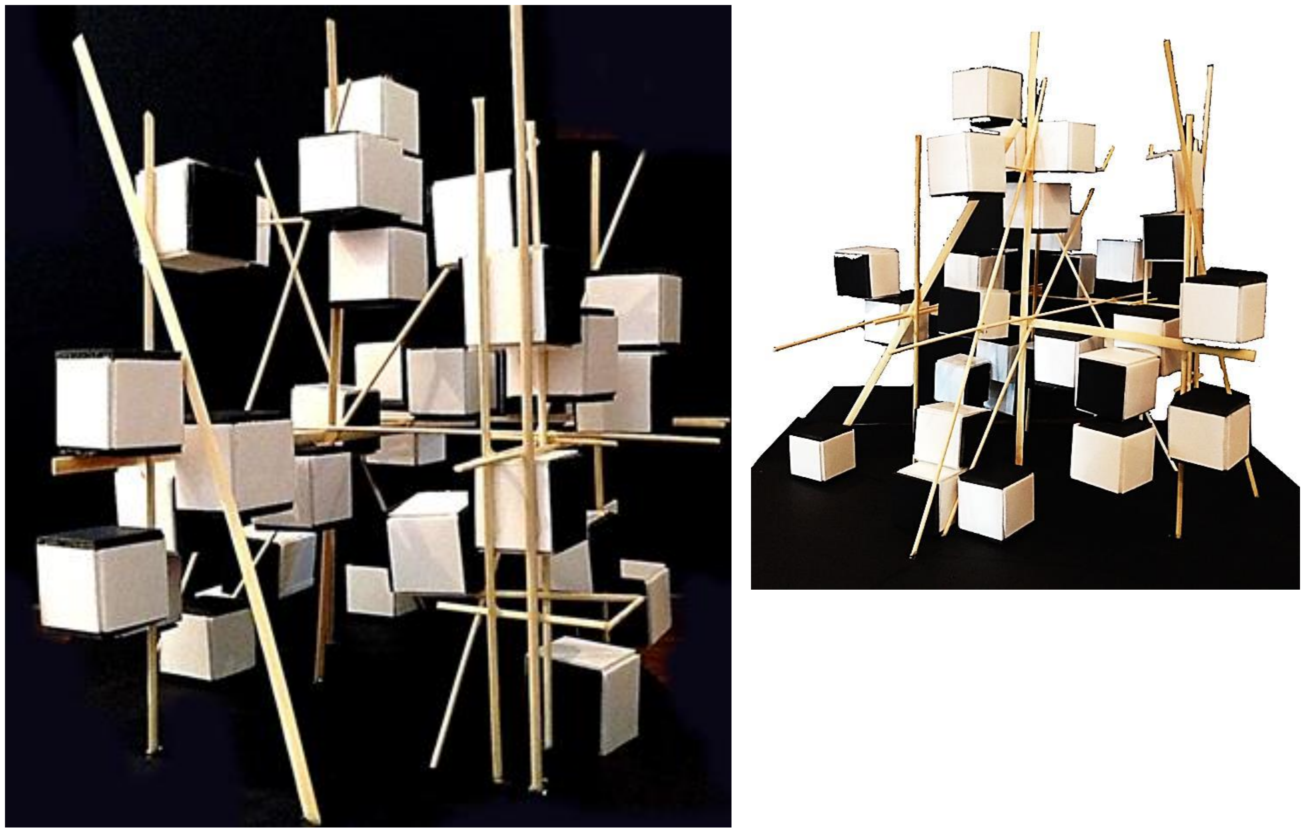

Fig. 6. Aloft architecture metabolism structures. Modern mega cities, researched volumes as future city modelling.

3. Discussion

Urban expanding, and needed city space is a global issue; hence, urban planning challenges can't be developed only for the present time. Furthermore, environmental concern design solutions are fundamentally necessary, aiming to accomplish higher public health conditions: we preserve quality of life, and our obligations for future generations as well. In this paper, we argue that modern future cities, must arise to be physically, and socially prepared for the great challenges of the upcoming decades. Presented models of researched volumes, visually describe interrelations of possible future architectural structures, and design concepts which constantly aim to preserve the ecology, environment, and biodiversity of ecumena. In this study, we conceptually conclude that in relation to the complexity of the urban planning, the land must be preserved without negative emanations of the so much needed human development. We argue that cities are complex ecosystems with a specific metabolism and it can be conceptually considered that cities are locally and regionally specific, especially, when the impact of urban growth and demographic volumes shifts, those events are very crucial challenges, always accompanied with contemporary demands, particularly for future modern cities. Hence, we must carefully further update, and develop spatial urban strategies regarding to the less known upcoming city challenges.

4. Conclusion

The Metabolism architectural concept early in 1960-s, was especially concern about future humanity wellbeing as a great global issue, moreover, those environmental actions as the group stated, can't be addressed only locally. Global and wide actions are irreplaceable and crucially necessary to maintain the public health conditions in appropriate scale of current, and future mega cities. The current state of cities, requires specific municipal's responsibilities in situations when we are facing potentially hazards for the public health. Hence, according to the conceptual conclusions of this research, we much prefer spatial patterns where the urban expand zones of the future cities, are more concentrated in high-rise structures, although preserving the land use for vegetation and environmentally healthy spaces, moreover, we further argue that in 'verticality' the high-rise structures can be considered and environmentally treated as future vertical farm mega cities. Urban planning issues, regarding to the: air pollution, climate changes, and public health hazards, fundamentally requires holistic integrated environmental actions. Global coordinated measures, as an environmental healing strategies.

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Interactive Architecture: Development and Implementation into the Built Environment

Kristina Boychenko [a, *]

[a] Polytechnic University of Milan, Italy

Abstract

The article explores Interactive Architecture as a new trend in design, based on communication of user and space, the ability of space to respond in real time and to accommodate different and changing needs of users in a more effective way, creating continuous relationship between society and built environment. It describes the emergence and development of interactive architecture, evolving through time, philosophy behind it and ways of implementation in the built environment, studying realized projects and means and tools required to obtain specific structural performance.

This article considers various types of interactive behavior, kinetic abilities and classification of systems, ensuring the responsiveness of interactive architecture. It shows a new approach to construction techniques and interdisciplinary collaboration of different fields, explaining why is it important to consider new trends and introduce embedded computation into structure on the early stages of design process in order to obtain the most effective spatial performance, ensured by abilities of interactive design.

Keywords: Interactive architecture, responsive design, space, behavior, design, embedded computation, structure, motion, information, swarm.

1. Introduction

The main key words of the modern life is the motion and the information. Now days it has become more obvious because of the development of information sources and ability to get any information fast and easy, and our habits to live in well-organized space full of devices becoming more fantastic day after day. The further the technologies and development go – the more requirements they meet and more questions they have to answer. In everyday life people tend to look unconsciously for the answers on questions they haven't asked yet. They want to be aware of everything and to communicate with each other and with the environment, becoming receivers, processors and mediums of the information. The static architecture is limited in its ability to interact with the changing circumstances and what is more important, with the users. It is frozen in one state while nowadays there is an ability to make it fluent, changing, communicating with people. People need an immediate response from the surrounding area and the modern technologies are able to provide it. Now the built environment can understand itself and better perform its function. It can understand people within it and outside, furthermore it can help them to understand themselves better.

* Corresponding author
E-mail addresses: tina.architect@gmail.com (K. Boychenko)

The dissolution of borders between silent and responsive, static and dynamic, emerges in society. For instance, frontiers between body and machine, interior and exterior, virtual and real tend to diminish thanks to innovation and technological progress. Nowadays, we can live at the same time in both real and virtual space. Even the cities are organized according to both physical and virtual activities. Therefore, one can wonder how to join these two extremes? How to keep the identity of place and body in such a fluctuating world? How can architectural objects keep their identity and, at the same time, be connected to the world, be everywhere? Stable identities as well as fixed space are no longer possible, because they do not correspond to the reality of today's world. This introduces a transformation of the real and mental space. Such a conversion asks for the invention of the new words and the new spaces, using new already invented techniques.

Interactive architecture is a recent phenomenon that is related to the development of new technologies. Interactive architecture transformed into stream of information, claims its continuous metamorphosis in space and time, it affirms the permeability between the body and the technology, between the subject and the space. This reminds us the conception of the Flesh of Merleau-Ponty, as the interactive architecture effaces the border between object and the subject. The body is considered as an interlacing of vision and of movement (Mahdalickova, 2009).

Using emerging images, light, sound, moving and changing its spatial configuration intelligent space makes the user sink into the atmosphere that is created for each of the activities taken within it and able to project information in the outer shell. Smart environment proposes the whole situation for the user to get involved into this conversation with the space, full of information, hidden or exposed possibilities, choice of activities, details, games and even jokes and allusions that the user is free to intemperate as his intelligence, experience and sense of humor lets him to.

Frank Lloyd Wright re-phrased a well-known quote of his mentor Louis Sullivan by saying that form and function should be one, joined in a spiritual union. It can be not only a narration about the space's function, but also an invitation, an engagement, a promise or a warning of what to expect of it. An answer on the questions before they appeared. In some way it should actually foresee the question to respond in a most correct way ("Frank Lloyd Wright", documentary).

2. Implementation into different space types

Numerous and widely diverse examples of interactive architecture, intelligent space and responding environment can be found in

- Public spaces,
- Living space (House Automation),
- Working space,
- Kids' space, and
- Medical environment

Interactive architecture has great benefits in optimization of structural performance of the building, especially when it has to deal not with people, but to response to the forces of nature. Right implementation of modern technologies and embedded computation in sustainable architecture can help in avoiding over-engineering, providing better climate control performance, shaping a more comfortable internal environment and safety in seismic areas. Not even mentioning how economically feasible it has become to use these technologies in improving energy consumption of the buildings.

3. Development-Philosophy

According to Betsky the architecture is not allowed to be frozen. It has to glow in all senses, to be like a fireplace gathering people around it, telling stories that unite us into a society (Cohen).

It's not enough just to build elegant compositions in plans and facades and to solve sculptural problems in modern society conditions. Architects are still aimed to do it but they also have to do it in terms of existing urban chaos, globalization and internet and mobile phones use, as Aaron Betsky puts it. The construction of separated buildings is not enough anymore. Architects cannot ignore the environment: messages and symbols, providing a non-stop information flow. In other words, a XXI century human lives in a reality different from the XX century, and the new shapes, functions and spatioal solutions are needed to ensure good relationship with this new environment.

Architecture cannot idealize the reality and distance itself from modern life anymore, imitating the styles from the past. The modern architecture knows no limits. It has no defined beginning and end, it's presence is everywhere. Virtual and real are entwined in one infinite and continuous space. Intangibility of architecture is the new feature of the modern times (Cohen).

Beauty comes from inside and at the same time is superimposed on the outer side of the product. Buildings are the complex adaptive systems, communicating with both external and internal environment (Belogolovskiy, 2006).

Interactive Architecture is architecture – interface, architecture – appliance. Interface defines the parameters, procedures and characteristics of the objects' interaction. The appliance performs the actions set by the interface. At the same interface can be built between the customer, the designer, manufacturer and environment.

From the point of view of degree of interactivity, interaction can be divided into following types:

• Linear interaction – when sent message is not related to previous messages;

• Reactive interaction – when message is related only to previous message;

• Interactive (Dialog) interaction – when the message is associated with a lot of previous messages and with the relationship between the two (Interactivity, 2010).

In similar way that the inert gases are not mixed with other gases, the objects that are not moving - do not communicate. Interaction is a kind of communication in motion. Interaction is not possible without motion.

4. Changeability, Uncertainty

Essentially, all the products begin to live when they are in the hands of the consumer, after the designer finished working on them. Project is a social process, it reinforces the idea of adaptation as a basic human desire.

Interactivity here should be seen as an active dialogue, and as a reactive interaction, i.e. corresponding to a single request. This adaptation can be expressed not only as an immediate response to this request, but also as an assumption of the change embedded during the design process.

The practice of post-occupancy evaluations (POE) is also relevant for considering this case. This entails a visit and evaluation of building after it was built and occupied by residents. Post-occupancy evaluation is intended not only for understanding how people actually use the facility together and how do they change the environment if they feel such a necessity, but also for the training of architects. It brings back the idea of the project as a process, and like the designers of the need to engage in as much as possible with the products or events after they are built. Most architectural projects do not imply regular post-occupancy evaluations because of financial limits. It should be assumed that the interactive project can be carried about in a way that makes financial sense, remaining equivalent to the post-occupancy evaluations (Hill, 2006).

The uncertainty principle works in Swarm Architecture. The result of the process is not predictable in traditional sense. Although the system is playing by the rules, the game outcome cannot be predicted. There are billions of possible outcomes, all of which are adequate as a response to requests of the system. Some results are more favorable to some experts, some are more favorable to the others, who limit the solution area, though still in the theory of infinity, a specific number of opportunities/options responds within the area of solutions. Nevertheless as it happens in sports, not all of the games are thrilling and beautiful. Strong and intelligent players are required to start an exciting game, experienced designer with a strong desire is required to perform with the best result. This understanding implies that the game takes place in accordance with the principles of uncertainty, probability and chance of quantum mechanics, something unexpected always might happen. Submitted in real-time the game is set for the unfolding fabric of reality. The player can surrender, the player can be much better than expected. If the project does not start the game, it is simply just modeling (Negroponte, 1995).

5. Digital Environment

Architecture reached the boarder of the digital and postdigital era. Not having time to learn and try out all the achievements of screen technologies, it began an experiment of reification of potential of information. Buildings are appointed with media properties of a screen, or on the higher level, turning them into polyactive gadgets with many interaction directions (Eshun, 2000).

In recent years architecture as a screen acquired a larger scale due to the simplification of the technological representation and relative cheapness and diversity in the interpretation of the Screen with its' pixel characteristics. The pixels are the data carriers, going through active development. The screens can be divided into two types according to the Pixel performance:

- surface screen projects
- mechanical screen projects

The surface screen projects include those that use light, representing the bacteria, the metamorphosis of materials. Such projects include the D-Tower by Lars

Finally architecture started to be based on it's changing performance in time, it's no more only simulation within isolated sectors of design process, it is a space-time experience. The experience of swarm architecture when the visitors start being connected through network, they communicate and flock together. Knowledge connects them, their intelligence is common, their contribution in collective design process gains effectiveness, growing in geometrical progression, that can be expressed through an equation of multiplication instead of summing up the contribution of each member. Independent intelligence is negligibly small in comparison with common one, when knowledge, sense, wisdom, emotions are now born in connection with the others. Development and very existence of any component of the system require network of similar components, ensuring the information exchange between them. The world becomes a whole installation space, the space that is being computed, creates new unexpected events by itself. The buildings are the new interface between the external environment conditions and the users (Mel, 2011).

6. Self organization

The world now goes through a technological revolution, the internet is going to be substituted by the new super-network, the grid, that would allow to use computational power remotely. This new network-environment would be able to visualize processing, memory and the communication, and to transform the computer resources of the world into a giant multi-processor with almost unlimited computational capability.

It is argued that architecture stands out in its ability to synthesize large number of mediums involved in the formation of design. Information exchange era brought non-trivial and simultaneously legible synthesis into high demand and increased engagement with complexity, so now architecture possesses a powerful tool to start the way towards applications beyond what is traditionally understood as a domain of design.

The matter as information enabled by computation brings architecture to the whole new level of operating information from the finer-grain physics of matter. This not only expands technically enriched material formations, but also activates previously hidden material powers toward designs beyond our anticipation in both formal imagination and performance.

The conception of swarm architecture introduced by Kas Oosterhuis may be considered as an alternative of accumulated super-power, in which all the members of the system behave according to specific algorithms, estimated by each member independently. This concept does not exclude possibility of all the elements' actions being controlled by one central computing node, distributing the computational power of all the grid (Oosterhuis, 2003).

7. Relationship between the nodes

One of the front men of integration virtual reality technologies and interactive architecture concepts, Kas Oosterhuis, develops his ideas through a system of easy rules, alternative to a system of data streaming. These ideas are based on some of the existing concepts, such as the Smart Dust (grids of very small simple, low-powered devices dubbed "motes" that monitor the environment and wirelessly pass data to a central collection point for analysis. The motes are linked to sensors which detect temperature, air flow or humidity, and wirelessly inform systems which monitor building security or manufacturing processes. The swarm basically is a Fractal Robot, made up of trillions of smaller bots, the active polymorphic materials made up of tiny identical nano-robots or foglets) or the Flock behavior.

This concept is based on construction of local relationshops, where the each node or each member of the system is aware of the neighbour but not aware of the whole system (the swarm, according to Oosterhuis) performance. Here the intelligence can not be programmed using top-to-bottom methods, it has to be a result of bottom-up evolution process of the system of members (nodes) relationship. This king of intelligence does not have to be intelligent by it's nature, it can emerge from a well organized collaboration of relatively stupid elements, all together they are able to create complex intelligence. This intellect should not be compared to human intellect though, it is more the a degree of communication complexity between different levels of operating devices. The same definition of intelligence works with the human brain functioning, transportation systes, expanding and reduction of citiesTaking into consideration understanding of this concept, the conclusion can be done: building components are similar to the motes, sending and receiving information. communicationg with the peering components of the same scale and to the other components on the otther level of the hyerarchy (Pister et al., 1999).

Interactive building behaves as a swarm, in which building elements are the members of the swarm. The members are a family with a large number of embedded computers and over time and technological development this number will increase. Some members have more intelligence, the others have less, but they are all important for the system. Each of them is rather stupid, as a bird, who needs to be just smart enough to stay in the swarm, operating only a limited amount of information for its task performance. The flocking behavior can be described in three simple rules:

- Cohesion: fly towards the centroid of the local flockmates;
- Separation: keep a certain distance away from nearest flockmates;
- Alignment: align the velocity vector with that of the local flock;

For a more precise parametric control over the flock two more rules can be added:

- Evasion: avoid occupying the same local airspace with the nearest flockmate. Evasion is a localized form of separation;
- Migration: fly toward a pre-specified location.

Similar rules can be implied to develop parameters and main algorithms of the building behavior. The building elements behave like intelligent elements, flocking the herd, re-configuring themselves in real time. Building elements behave like boids. Swarm behavior of building boids is evolution in progress since it immerses digital life into our daily lives and into the very fabric of building materials. Building boids are senders and receivers of information, exchanging data, processing incoming data, and proposing new configurations as the outcome of the process (Oosterhuis, 2003).

Nevertheless the different shapes of flocks are recognizable as a complex whole. The importance of architectural design process here is that the whole structure performance should not be determined in its' exact and complete form, in advance setting all the individual components into a consistent whole. The designer can work with simple rules that start generating relevant data with the associated positions of nodes for the production of mass customization. Also the behavior of nodes may be used to form the shape of the construction by setting the area of the moving flocks by limiting their space and leaving a valid possibility for movement, as each building or it's component must take into account the presence of other objects in their urban context.

Generally everything surrounding us in space and everything we see around, every car, every street, every town is based on simple calculations, creating a complex behavior that for which it is almost impossible to recognize and track all the rules. The only way to find them out is to run the system, to design a system that is based on simple rules generating complexity. This assumption potentially turns the designers into researchers, that need to set complex systems and operate them. Performative architecture brings the designer to genetic core of what we see around us.

8. Senses

With the development of new technical capabilities, "smart objects" start being able to receive a lot of information from the external environment. The people's behavior is a significant part of this environment. This leads to necessity of understanding the feedback with the world and the notion of "family of smart objects" in our environment that can communicate with us and with each other by sending messages using the built-in microprocessors which are giving different information. A lot of these components are designed to capture information from the environment, such as temperature, light levels, wind speed and noise. Some components are able to receive simple messages from the man. They feel our presence radiated heat or movement and react in some way (Mel, 2011).

The ultimate goal of Swarm architecture is to keep its' new structures up-to dated in real time. The objective of information architecture projects is to support the vitality of the process and apply the values to the behavior in real-time, to understand how can the designers create a tunnel for a continuous flow of data within the built structure, where the content is constantly changing in real time? To facilitate this fundamentally new view of the world, we have to look at the building as if they are appliances that can be run in real-time. Dynamic buildings can be considered as existing processes that continuously inform users and are informed themselves continuously during other active processes. They are the active nodes in a complex adaptive operating network.

9. Conclusion

Using the new techniques, people cooperate to create efficient buildings, which are considered as highly applicable processes. The buildings become active installations, where multiple control devices are constantly communicating with other control devices, their users and their environment. We know from practice that there is a large proportion of the budget devoted to electrical and mechanical installations for every building, taking up to 30 % of the total budget. In the bright future of buildings, the entire structure will be interpreted as the installation. Projecting current trends into the near future, it makes sense to consider all the components of built structure as active members of the installation. The building becomes the instrument, it becomes an installing itself (Andrasek).

The importance of Interactive Architecture in fast developing society with new fascinating technologies is hard to overestimate from different points of view. It brings physical, social, psychological and economical benefits. There are no doubts it will find more and more implementations in modern Architecture.

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Design Principles of Multifunctional Microreactors for Hydrogen Production via Ammonia Decomposition

Junjie Chen [a, *]

[a] Department of Energy and Power Engineering, School of Mechanical and Power Engineering, Henan Polytechnic University, Jiaozuo, Henan, China

Abstract

Aiming at developing general design guidelines of integrated multifunctional microreactors, ammonia decomposition thermally coupled with methane catalytic combustion in catalytic microreactors for hydrogen production was studied numerically. The effect of flow configuration on the operation characteristics was studied, using a two-dimensional computational fluid dynamics model. Different performance measures were evaluated to assess the operability of the reactor. It was shown that complete conversion of ammonia can be obtained in both flow configurations. A proper balance of the flow rates of the decomposition and combustion streams is crucial in achieving this. For a given flow rate of combustible mixture, material stability determines the lower power limit, whereas the maximum power generated is determined by extinction at large decomposition stream flow rates. The two flow configurations were contrasted based on multiple performance criteria. They were found to be practically equivalent for highly conductive materials. Using properly balanced flow rates, the co-current flow configuration expands the operating regime to low and moderate thermal conductivity materials as compared to the counter-current flow configuration that exhibits a slightly superior performance but in a rather narrow operating regime of highly conductive materials and high ammonia flow rates.

Keywords: Reactor design, Multifunctional microreactor, Ammonia decomposition, Hydrogen production, Process optimization, Catalytic combustion

1. Introduction

Micro-chemical devices are actively being developed as next generation portable power sources due in part to the superior gravimetric energy density of typical liquid fuels compared to lithium-based batteries (Holladay and Wang, 2015). Such a power generation device may consist of a fuel processor, which acts as a hydrogen source, coupled with a proton exchange membrane (PEM) fuel cell. Hydrogen production can be achieved through a number of reactions, i.e., partial oxidation, steam reforming, and auto-thermal reforming of hydrocarbons or alcohols, or cracking of ammonia. Most of these reactions have been carried out in catalytic microreactors. The ammonia decomposition route is particularly attractive for proton exchange membrane fuel cells, as its products are free of carbon monoxide that poisons the fuel cell catalyst and, thus, this route could minimize downstream processing, by eliminating the water-gas shift and the preferential oxidation of carbon monoxide steps (Regatte and Kaisare, 2013). Among these routes,

* Corresponding author
E-mail addresses: cjjmmm@163.com (J. Chen)

most reactions are endothermic. Therefore, energy must be supplied through an exothermic reaction, such as combustion. The thermal coupling between a combustor and a reformer becomes then an important part of developing stand-alone, multifunctional reactors in which the heat exchange and chemical reaction are coupled in the same device.

The coupling of endothermic and exothermic reactions can be achieved in a number of ways. One strategy is to use "direct" coupling where both reactions are carried out simultaneously in the same reactor using a suitable bi-functional catalyst (Ramaswamy *et al.*, 2006). A second strategy is "temporal" coupling of the two reactions, where the exothermic and endothermic reactions are alternately carried out in the same reaction chamber (Kolios *et al.*, 2000). The final heat integration strategy involves "spatial segregation". In this approach, the exothermic and endothermic reactions are carried out in different reaction chambers that are separated by a heat-conducting medium. Spatial segregation allows an independent choice of fuel, of catalysts, and of reaction conditions for the combustor and the reformer. This flexibility in conjunction with the small feature size of a microreactor, which facilitates heat transfer, renders this approach suitable for microreactors (Stefanidis and Vlachos, 2009). Traditionally, the counter-current mode of heat exchange has a better performance. Recent work has demonstrated an advantage of the co-current flow configuration in lowering catalyst temperature, due to the overlap of reaction zones (Deshmukh and Vlachos, 2005). However, enhanced transport rates due to small size of microreactors have an impact on the temperature distribution thereby affecting the choice of flow configuration. For example, one can envision nearly isothermal reactors under certain conditions, where co-current and counter-current systems are essentially equivalent. Therefore, the best heat exchange mode at the micro-scale is not obvious and may differ from that of large-scale reactors.

In this study, a spatially segregated mode of the coupling of endothermic and exothermic reactions was investigated in parallel plate multifunctional microreactors, using a two-dimensional CFD (computational fluid dynamics) model for co-current and counter-current flow configurations, where ammonia decomposition over ruthenium was coupled with methane catalytic combustion. The latter was chosen to enable high temperatures and complete conversion within short contact times while eliminating problems associated with catalyst deactivation. Furthermore, the effect of flow configuration on operation maps of coupled reactors using various performance measures was explored. The objective of this study is to develop general design guidelines of integrated multifunctional microreactors.

2. Numerical models and simulation approach

2.1. Geometric model

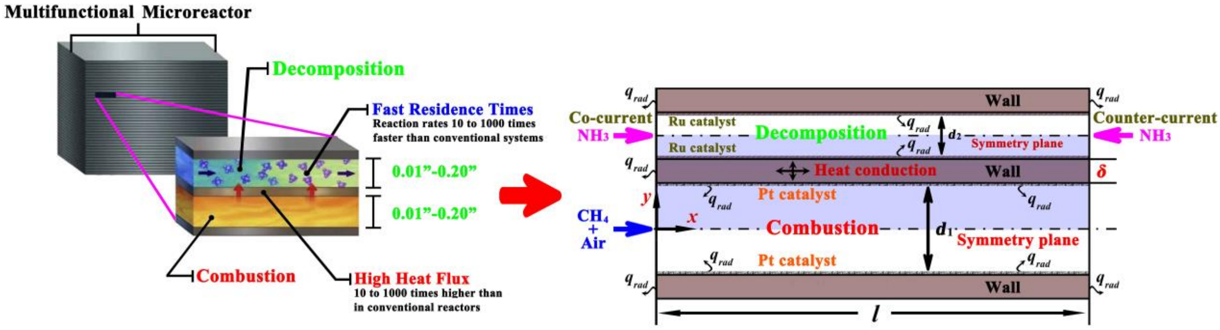

Fig. 1. Schematic diagram of the simulated parallel plate multifunctional microreactor with alternating combustion and decomposition channels

An integrated parallel plate microreactor geometry is simulated. The combustion and decomposition reactions are carried out in alternate channels separated by walls, as shown schematically in Figure 1. The combustion channel is 0.6 mm wide, the decomposition channel is 0.3 mm wide, and the wall is 0.3 mm thick. The reactor length is 20.0 mm. The stoichiometric methane-air flow in the combustion channel is either co-current or counter-current with respect to the pure ammonia flow in the decomposition channel, which has ruthenium catalyst deposited on the channel walls. The ammonia decomposition reaction occurs at the catalytic channel wall resulting in hydrogen production. Unless otherwise stated, the methane-air inlet flow velocity is

0.8 m/s. Both the fluid streams enter the reactor at ambient temperature. Using the inherent symmetry of the geometry, only one-half of each channel and the connecting wall are simulated. The fluid flow as well as the heat and mass transfer equations are solved in the fluid phase and the energy balance is explicitly accounted for in the solid walls.

2.2. Mathematical model

The assumptions made are as follows: a steady state is considered; the ideal gas law is assumed; a laminar flow is employed in each channel because the Reynolds number (Re) based on the incoming properties and the channel hydraulic diameters is less than 480; gravity is not considered because it is found to have minimal impact on the computational results for the Reynolds numbers of this study. A two-dimensional steady state model is employed using the commercial CFD software package ANSYS FLUENT® Release 6.3 (Fluent 6.3 user's guide, 2006) incorporates with the detailed homogeneous and heterogeneous reaction schemes in CHEMKIN (Kee *et al*., 1996) and Surface-CHEMKIN (Coltrin *et al*., 1996) format to solve the steady state continuity, momentum, energy, and species equations with appropriate boundary conditions. At the vertical wall faces of each parallel plate, both convective and radiative boundary conditions are applied to compute external heat losses. Since the heat recirculation within the wall profoundly affects the combustion stability, the heat conduction within the walls is considered.

2.3. Chemical kinetics

For the catalytic combustion of methane-air mixtures over platinum, the detailed heterogeneous reaction scheme of Deutschmann *et al*. (2000) is employed. A surface site density Γ_{Pt} = 2.72 × 10^{-9} mol/cm^2 is used for the platinum catalyst (Deutschmann *et al*., 2000). For the ammonia decomposition over ruthenium, the detailed heterogeneous reaction scheme of Deshmukh *et al*. (2004) is employed. A surface site density Γ_{Ni} = 2.90 × 10^{-9} mol/cm^2 is used for the ruthenium catalyst (Deshmukh *et al*., 2004). The computational tool DETCHEM (Deutschmann *et al*., 2014) is applied to treat the problem numerically. Gaseous and surface thermodynamic data are included in the provided schemes. Mixture-average diffusion coefficients are used in conjunction with the CHEMKIN transport database (Kee *et al*., 1998).

2.4. Computation scheme

The fluid density is computed using the ideal gas law. The individual properties of various gaseous species are computed using the kinetic theory of gases, whereas the specific heats are determined as a function of temperature using polynomial fits (Norton and Vlachos, 2003). Mixture properties, such as specific heat and thermal conductivity, are computed from pure component values based on the mass-fraction weighted mixing law (Norton and Vlachos, 2004). Binary species diffusivities are determined using the Chapman-Enskog equation and then are used to compute the multicomponent mixture diffusivities. For the solid wall, a constant specific heat and an isotropic thermal conductivity are specified. Given that material thermal conductivity varies with temperature and more importantly with the material chosen, simulations are carried out over a wide range of wall thermal conductivities. An adaptive meshing scheme is used for the discretization of the differential equations. The computational mesh is initialized with 200 axial nodes, 80 radial nodes for the combustion channel and the wall sections, and 60 radial nodes for the reforming channel. This initial mesh is adapted and refined during a computation to increase the accuracy of the solution in regions of high gradients. Specifically, additional nodes are introduced to refine the mesh using the tools built in the computational software so that the normalized gradients in temperature and species between adjacent cells are lower than 10^{-6}. Adaptation is performed if the solution has not converged after about 10^6 iterations or when the residuals are around 10^{-6}. This last threshold, while not optimized, is meant to strike a balance between cost and probability for convergence. Specifically, mesh refinement before achieving complete convergence reduces the computational effort, but a too early refinement, i.e., in a few iterations, may lead to refinement in wrong regions. After mesh refinement, a total of 80000-600000 nodes are used. Such an adaptive meshing strategy, starting with a relatively coarse initial mesh followed by refinement in regions of large gradients, achieves an adequate balance between accuracy and computational effort.

The model boundary conditions are described as follows. Danckwerts boundary conditions are implemented for the species and temperatures at the inlets to better mimic experimental conditions (Sui and Mantzaras, 2016). The reactor exits are held at a fixed atmospheric pressure and the normal gradients of species and temperature, with respect to the direction of the flow, are set to zero. Symmetry boundary condition is applied at the centerline of both channels, implying a zero normal velocity and zero normal gradients of all variables (Sui *et al.*, 2016). No-slip boundary condition is applied at each wall-fluid interface. Continuity in temperature and heat flux is applied at the fluid-solid interfaces. It should be noted that neither heat-transfer nor mass-transfer correlations are employed since detailed transport within the solid and fluid phases is explicitly accounted for. The full problem is solved through a segregated solver using an under-relaxation method. Convergence of the solution is monitored through the residuals of the governing equations. The solution is deemed converged when the residuals of the equations are less than 10^{-6}. The coupling of the heat equation in the wall and the reacting flow equations makes the problem stiff because of the disparity in thermal conductivity between the gases and the wall. Parallel processing using a MPI (message passing interface) is used to speed up the most demanding computations. Natural parameter continuation is employed to study the effect of various operating parameters.

3. Results and discussion

Lower reactor temperatures are essential for the stability of catalyst and construction materials employed in the ammonia decomposition channel. In this study, an arbitrary maximum temperature of 1500 K is proposed as the material stability limit, i.e., wall and catalyst temperatures in excess of this value are deemed detrimental to the reactor. The choice of the temperature threshold defined here stems from similar temperatures observed in short contact time reactors, in which noble metal catalysts have been found to be stable up to temperatures of 1500 K (Torniainen *et al.*, 1994). Additionally, supported ruthenium catalysts have been found to be stable for periods of 100 hours tested (Berman *et al.*, 2005).

3.1. Effect of wall thermal conductivity

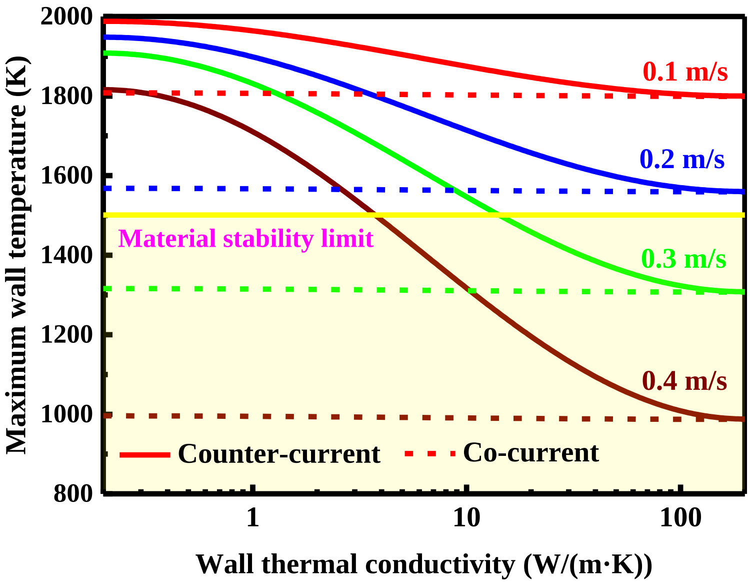

Fig. 2. Effect of wall thermal conductivity on the maximum wall temperature. The shaded region indicates the material stability limit

The wall thermal conductivity is an important parameter which determines the reactor stability. Figure 2 shows the effect of wall thermal conductivity on the maximum wall temperature at various ammonia inlet flow velocities. For highly conductive materials, the temperature profiles of the two flow configurations are nearly identical. The high wall thermal conductivity implies rapid heat conduction that results in nearly isothermal wall temperatures. In this case, the time-scale of wall heat conduction is much smaller than the residence time rendering the effect of flow configuration secondary. However, with the decrease of wall thermal conductivity, differences between the two flow configurations emerge. In the counter-current flow configuration, the heat generation and heat removal are separated by the length of the reactor, and a low wall thermal conductivity implies slow heat transfer resulting in very hot walls near the combustion zone.

In addition, significant temperature gradients may occur within the wall. Almost identical behavior of the two flow configurations is observed for high thermal conductivity materials. The maximum temperature of a co-currently coupled reactor is nearly independent of wall thermal conductivity, whereas a counter-currently coupled reactor exhibits very high wall temperatures at lower wall thermal conductivities. The shaded region demarcates the operating regime of allowable reactor temperatures. Co-current operation results in lower reactor temperatures and allows a wider choice of materials than that of the counter-current flow configuration.

3.2. Power exchanged

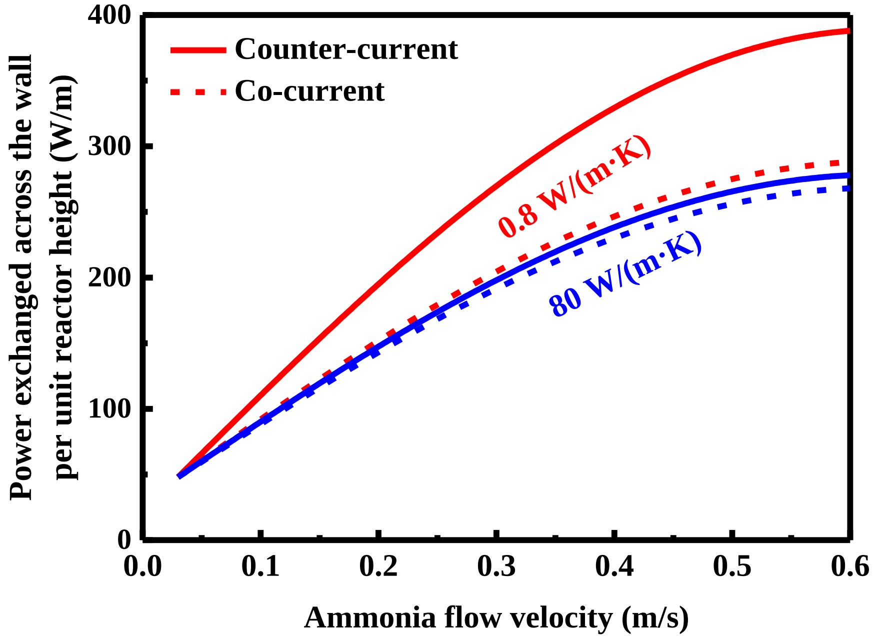

Fig. 3. Effect of ammonia flow velocity on the power exchanged across the wall per unit reactor height for select wall thermal conductivities

The power exchanged across the wall is an important performance measure since a primary objective of a multifunctional reactor is to maximize the heat exchange between the two reaction zones. Previously, the critical power removed at extinction has been used as a stability criterion for gaseous micro-combustors (Kaisare and Vlachos, 2007). Figure 3 shows the power exchanged per unit height of the reactor as a function of ammonia flow rate for different wall thermal conductivities. The end points of the curves at high ammonia flow rates correspond to the critical power exchanged prior to extinction. In the co-current flow configuration, the power exchanged is practically independent of the material chosen. On the other hand, a strong dependence of the power transferred on the wall thermal conductivity can be observed in the counter-current flow configuration, especially at high ammonia flow rates. The powers exchanged in the two flow configurations become practically equal for highly conductive materials, corresponding to metals and high conductivity ceramics, where the time-scale of axial heat conduction is so short that heat transfer is independent of the flow configuration. At the other extreme of low wall thermal conductivity, the time-scale of transverse heat conduction becomes larger than the residence time rendering the effect of flow configuration small. However, for moderate wall thermal conductivities, there is a competition between the heat conduction time-scale and flow residence time, and therefore, the flow configuration plays a role in heat exchange. In particular, the power exchanged in the counter-current flow configuration is larger for moderate conductive materials. Materials in this conductivity range, corresponding to high temperature ceramics such as alumina and silica, have previously been used for the fabrication of micro-combustors (Miesse *et al.*, 2004) and have been reported to be most stable to heat losses (Kaisare *et al.*, 2008). Therefore, the two flow configurations show nearly identical performance at the extremes of material conductivity range in terms of the power exchanged, but the counter-current flow configuration is better for moderate wall thermal conductivities.

3.3. Exit gas temperature

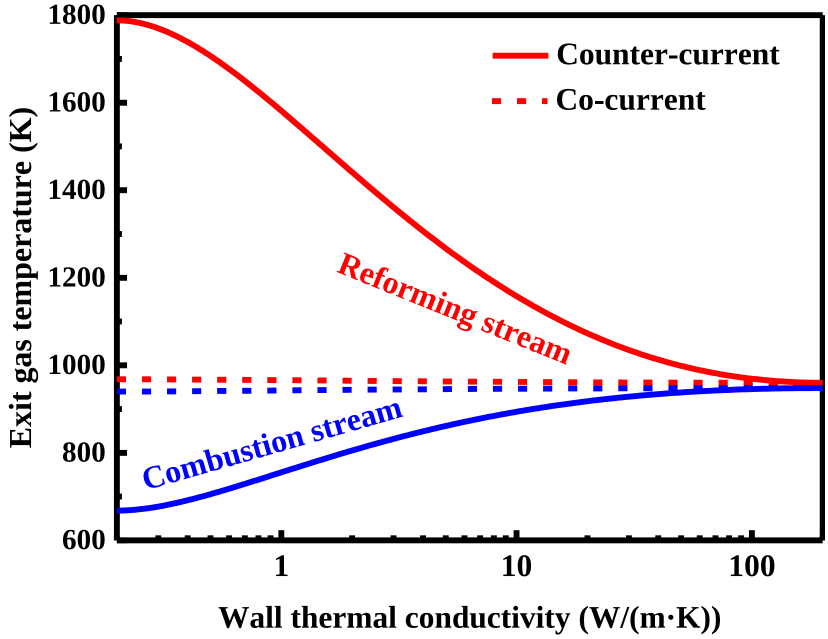

Fig. 4. Effect of wall thermal conductivity on the exit gas temperatures

Figure 4 shows the exit gas temperatures as a function of wall thermal conductivity. The ammonia inlet flow velocity is 0.8 m/s. In the counter-current flow configuration, the larger power exchanged comes at the cost of larger maximum wall temperature, higher exit temperature of the decomposition stream, as it flows past the hot combustion zone, and a lower combustion stream exit temperature. High temperatures of the decomposition stream are undesirable for proton exchange membrane fuel cell applications where the stream has to be cooled down to about 360 K (Djilali, 2007). Note that the proton exchange membrane fuel cell is a promising alternative power source for various applications in portable power device, vehicles, and stationary power plants (Wu, 2016). Therefore, a comparison in terms of the critical power exchanged may be misleading and thus not a good performance criterion for integrated reactors producing hydrogen. These numerical results indicate the rather expected outcome that optimizing individual components, e.g., a combustor and a reformer, is not necessarily a good strategy for developing design principles for coupled reactors.

3.4. Hydrogen production

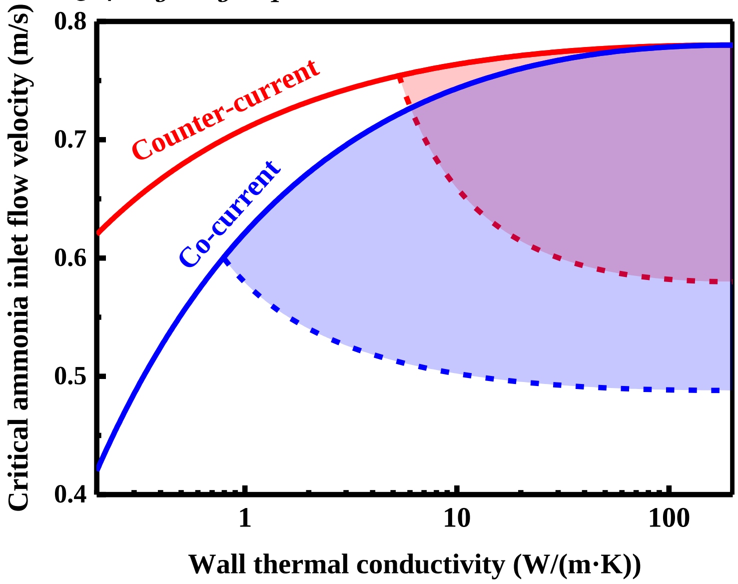

Fig. 5. Effect of wall thermal conductivity on the critical ammonia inlet flow velocity. The shaded region demarcates the operating regime delimited by extinction and material stability

The hydrogen flow rate is perhaps the most important performance measure of an integrated reactor. It depends not only on the ammonia flow rate but also on the ammonia conversion. Figure 5 shows the critical ammonia inlet flow velocity as a function of wall thermal conductivity. The critical ammonia inlet flow velocity corresponds to extinction. For a given wall thermal conductivity, any ammonia inlet flow velocity above the critical one, i.e., above the line connecting the points cannot be self-sustained. Therefore, operation is limited below the line of each flow configuration. Larger wall thermal conductivities result in increased heat recirculation and therefore aid in stabilizing higher ammonia flow rates, irrespective of the flow configuration. The overlap of reaction zones in the co-current flow configuration results in diminished stability of the reactor, i.e., lower maximum ammonia flow velocities, especially for highly insulating materials. However, the difference in stability between the two flow configurations becomes less pronounced for highly conductive materials. Given that low ammonia flow rates result in high wall temperatures, the shaded areas indicate a coarse operating regime of realizable flows and wall materials. The upper boundary of flow is determined from extinction, whereas the lower boundary of flow and wall thermal conductivity from the material stability limit. The materials limit criterion renders the counter-current flow configuration only slightly better for a narrow range of materials. It is clear that the co-current flow configuration allows a wider choice of wall materials.

3.5. Maximum power generated

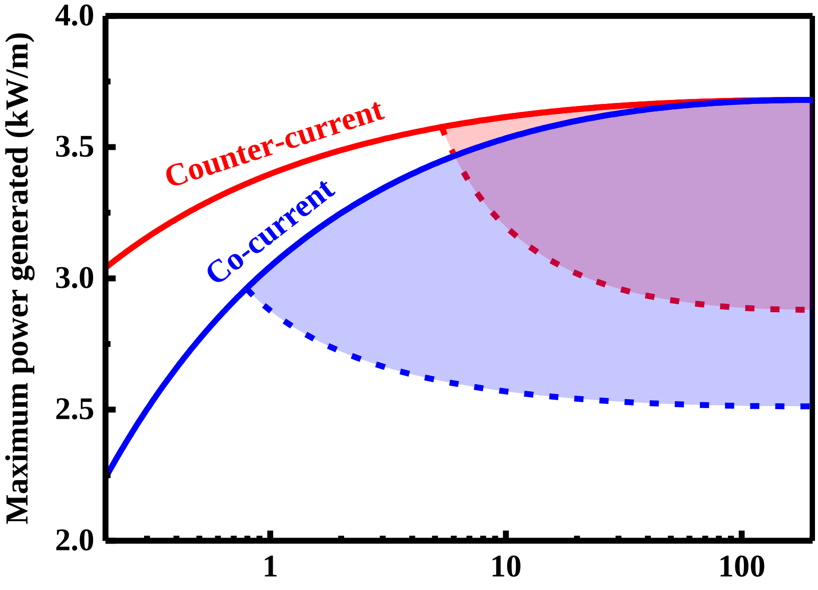

Fig. 6. Effect of wall thermal conductivity on the maximum power generated based on the hydrogen produced. The shaded region demarcates the operating regime delimited by extinction and material stability

The maximum power generated corresponds to the maximum hydrogen yield. Depending on the overall process flow sheet, operation with the maximum power generated may be desirable. Figure 6 shows the maximum power generated per unit reactor height from the hydrogen produced as a function of wall thermal conductivity. The maximum power generated accounts for both the critical ammonia flow rate and the ammonia conversion, assuming 100 % fuel cell efficiency. The shaded region demarcates again the operating regime delimited by extinction and material stability. Due to the high conversions under reasonable operating conditions, the similar features of the critical ammonia inlet flow velocity can be obtained. The counter-current operation is slightly better in a narrow operating regime. The co-current flow configuration allows a wider choice of fabrication materials and catalysts.

3.6. Operation map

In this section, operation maps are presented in order to guide the design of integrated reactors based on a projected power requirement. While these operation maps clearly pertain to parallel plate geometries of fixed dimensions and to the specific fuels, the approach employed herein is general and similar findings are expected for other multifunctional micro-chemical devices. A 100% fuel cell efficiency is assumed in all computations, given that a lower efficiency would scale the results exactly proportionally. Based on the discussion above, only a narrow range of powers can be achieved for a fixed methane-air flow rate. The minimum power is determined from the lowest allowable ammonia flow rate that in turn is dictated by the material limit set at 1500 K. The maximum power corresponds to the critical value prior to extinction. The minimum power generated corresponds to the co-current flow configuration, whereas the maximum power generated corresponds to the counter-current flow configuration at high wall thermal conductivities. Powers outside this range cannot be achieved irrespective of the flow configuration or wall material chosen. One could envisage a "scale-out" type of approach (Mettler *et al.*, 2011), using multiple units in parallel, to achieve higher powers or changing the reactor dimensions to enable lower powers, while keeping the residence time constant (Stefanidis and Vlachos, 2008). It should be noted that the computed powers are dependent on the choice of fuel. However, given a single reactor consisting of two channels only with fixed channel length, operation outside this power range without changing the fuel implies varying the methane-air flow rates.

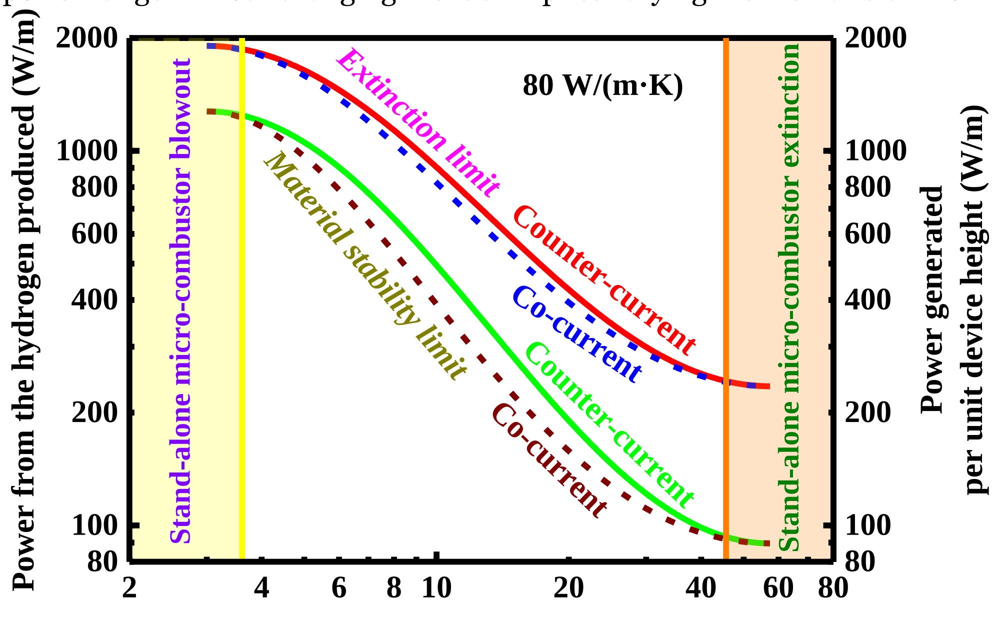

Fig. 7. Operation map indicating the power generated based on the hydrogen produced as a function of methane-air residence time. The vertical shaded areas indicate those for a stand-alone micro-combustor.

The fuel-air residence times in micro-combustors have been found to be restricted to a finite operating regime for self-sustained combustion (Wan *et al.*, 2016). Very fast fuel-air flows cause blowout, given that the residence time is not long enough for self-sustained operation to be possible; in contrast, very slow flows result in extinction, since not enough heat is produced to keep up with the heat loss to the surroundings (Yan *et al.*, 2016). A two parameter continuation is used to track the power generation as a function of the ammonia flow rate for various methane-air residence times. Figure 7 shows the operation map indicating the power generated based on the hydrogen produced as a function of methane-air residence time. The shaded vertical rectangles provide an idea of the residence time limits. The limits of the operating regime depend on the choice of flow configuration as well as the wall material. High wall thermal conductivity represents the maximum power produced and also results in an equivalent performance of the two flow configurations. Therefore, the counter-current flow configuration with a high wall thermal conductivity of 80 W/(m·K) is chosen for the majority of runs and CFD simulations are performed for different methane-air residence times. A narrow operating regime is achieved, as indicated by the cross-hatched area. For both flow configurations and all methane-air residence times, an upper bound for the power is caused by the critical ammonia inlet flow velocity, whereas the lower bound depicts the material limit in terms of the reactor temperature. A balance between the methane-air and ammonia flow rates is crucial in enabling self-sustained operation of a coupled microreactor. Stable operation outside the methane-air residence time regime predicted by CFD simulations of the stand-alone micro-combustor is also an evidence of the enhanced stability of the integrated reactor. The power generation plots can be used as a guide in designing integrated microreactors. One can select a desired power, and trace it to the operating regime to estimate the required methane-air residence time.

4. Conclusion

The ammonia decomposition over ruthenium thermally coupled with the catalytic combustion of methane-air mixtures over platinum in multifunctional microreactors for hydrogen production was studied numerically. Computations were carried out to develop general design guidelines of integrated multifunctional microreactors, using a two-dimensional CFD model that included detailed chemistry and transport. Two flow configurations, i.e., co-current and counter-current, were contrasted in terms of various performance criteria including reactor temperatures, temperature of exit gas stream, maximum power exchanged, and hydrogen production achieved. For any combustible flow rate, the operating regime of a microreactor is delimited by extinction caused from fast ammonia flows and by material stability, in terms of reasonable reactor temperatures, at sufficiently slow ammonia flows.

For highly conductive materials, the co-current and counter-current flow configurations behave similarly in all performance measures simply because high wall thermal conductivity coupled with small reactor scales renders the operation nearly isothermal. The co-current flow configuration enables lower reactor temperatures and a wider spectrum of materials to be used, whereas the counter-current flow configuration shows superior performance albeit in a very narrow operating regime of high ammonia flow rates and highly conductive materials. Since this advantage of the counter-current flow configuration is only slight, the co-current flow configuration should be preferred for actual reactors.

Finally, while the catalytic combustion of fuel-air mixtures can lead to result in high temperatures and drive ammonia decomposition to completion in milliseconds, meanwhile it results in a relatively narrow range of balanced flow rates in order to prevent material stability and avoid extinction issues. Future work will explore the use of alternative coupling modes and chemistries in order to broaden the operation regime.

5. Acknowledgement

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Informational Structural Modeling

V.Ya. Tsvetkov [a, *]

[a] Moscow technological University (MIREA), Russian Federation

Abstract

This article describes a new approach to the structural modeling of empirical data. This approach is based on the information structural modeling. Data modeling is a general structural view of deterministic and statistical structural modeling. News structural modeling based on the use of information of the situation, construction information and information units. News structural modeling allows you to build linear and non-linear structure, including the structure of systems with feedback. The article shows the relationship of information as the basis for the construction of structures of phenomena or objects.

Keywords: information, empirical data, structural modeling, Trinitarian systems, statistical methods, information construction information relations, informational approach.

1. Введение

В настоящее время термин структурное моделирование применяется широко и в разных направлениях (Singh et al., 2003). Это обусловлено тем, что объектом моделирования может быть широкий спектр технических и социальных объектов. Этим понятием обозначают функциональное и системное моделирование, связанное с созданием новых систем (Marca, McGowan, 1987). Этим понятием обозначают в отдельных случаях структурный анализ, связанный с анализом в области психологии и социологии (Hibbeler, Kiang, 2015). Структурное моделирование связывают с объектным моделированием. Структурное моделирование применяют в лингвистике для анализа языковых конструкций. Структурное моделирование связывают с латентным анализом. В психологии и социологии структурное моделирование связывают с методами построение структуры неявных переменных на основе исходных эмпирических коллекций (Westland, Christopher, 2015). Перечисленные направления связаны либо с аксиоматическим подходом, либо с эмпирическим подходом. Теории как таковой в этих подходах не было, хотя методики были и есть. Информационное моделирование (Sudarsan et al., 2005; Tsvetkov, 2016) содержит многочисленный инструментарий для решения задач структурного моделирования, но вплотную такая задача в информационных технологиях не возникала.

2. Материал и методы исследования.

В качестве материала использовались существующие исследования в области статистического структурного моделирования. Использовался опыт работ в области детерминированного структурного проектирования. Использовался опыт работ в области информационного конструирования. В качестве методики исследования применялся

* Corresponding author
E-mail addresses: cvj2@mail.ru (V.Ya. Tsvetkov)

системный анализ, структурный анализ, ситуационный анализа и информационное моделирование.

3. Результаты исследования

Исследование направлений информационного структурного моделирования. Информационное структурное моделирование имеет много различных реализаций. Выделим следующие направления применения структурного информационного моделирования: создание или проектирование технических или технологических объектов (системы, технологии, проекты); исследование структуры объекта или явления; выделение из аморфной совокупности данных структуры при явном задании исходной совокупности; выделение из аморфной совокупности данных структуры при наличии скрытых (латентных) переменных в исходной совокупности, применение информационного моделирования для создания структуры.

Из множества методов можно выделить два класса: статистические (включая вероятностные) методы формирования структуры; формирование структуры на основе информационного моделирования (включая дихотомию и оппозицию). В обеих группах результатом моделирования является информационная конструкция (Tsvetkov, 2014b) как отражение структуры.

Статистический подход структурного моделирования. Суть статистического подхода показана на рис. 1.

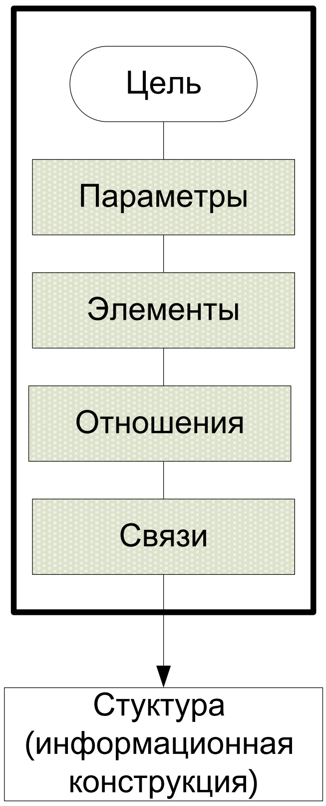

Рис. 1. Статистический подход формирования структуры.

Распространенным методом структурного моделирования при этом подходе является применение уравнений структурного моделирования (Structural equation modeling – SEM) (Westland, Christopher, 2015; Kline, 2010), которое полностью соответствует этапам на рис. 1. Построение структуры согласно схеме 1 происходит сверху вниз.

Применение уравнений структурного моделирования реализуется в виде наборов математических моделей и статистических методов, которые приводят к построению структурных конструкций эмпирических данных. Подход SEM включает разнообразный набор методов: факторный анализ, «анализ пути», скрытое моделирование роста и другие. Этот подход не следует смешивать с концепцией структурных моделей в эконометрике и структурными моделями в экономике.

Отличительными особенностями SEM является применение двух моделей: *структурной модели*, показывающей причинные связи между эндогенными и экзогенными переменными; *модели измерений*, показывающей отношения между латентными переменными и их явными показателями.

Одной из широко применяемых методик в статистическом подходе структурного моделирования является анализ пути (path analysis) или диаграммы пути (path diagrams) (Eichler, 2007). Анализ пути используется для описания направлений (пути) зависимостей между эмпирическими переменными, включая латентные. С концептуальных позиций path analysis и path diagrams представляют собой анализ информационной ситуации (Tsvetkov, 2012), которая формируется на основе специфических описаний, включающих латентные информационные единицы (Tsvetkov, 2014a). Информационные единицы составляют основу будущей структурной конструкции. Существует еще ряд методов, но общий принцип всех методов состоит в статистической обработке наблюдений и построение структуры на основе статистической обработки, связывающей эмпирические и скрытые параметры.

Уравнения структурного моделирования применяют в социологии, психологии и других социальных науках. Этот подход часто применяют для выявления скрытой конструкции. При этом фактически осуществляется построение информационной конструкции, но не в терминах информационных технологий, а в вероятностных и статистических терминах. Элементы теории уравнений структурного моделирования в терминах информационных технологий являются информационными единицами. Название метода «уравнения структурного моделирования» является общепринятым, но не удачным. По существу речь идет не об уравнениях, а о методах анализа эмпирических данных и построения некой скрытой структуры, которую называют конструкцией. Интеграция этих методов с информационным конструированием может существенно развить данное направление и способствовать развитию новой теории структурного моделирования.

Информационный подход структурного моделирования. На рис. 2. приведена концептуальная схема построения информационной структуры.

Рис. 2. Концептуальная схема построения структуры на основе информационного подхода.

Построение структуры согласно схеме рис. 2 происходит снизу вверх. На рис. 2 показаны основные факторы информационного структурного моделирования. Принципиальным является применение информационных единиц (Tsvetkov, 2014a), которые играют роль алфавита при моделировании. Это придает системность моделированию и сопоставимость получаемым структурам.

Общие принципы структурного информационного моделирования при проектировании и формировании нового объекта включают следующие этапы: Задание элементов моделирования – информационных единиц; Задание синтаксиса; формирование информационных связей и отношений; Построение информационной конструкции.

Общие принципы структурного информационного моделирования при выявлении структуры объекта включают следующие этапы: Выявление связей и отношений. Дихотомическое деление объекта, оппозиционное деление объекта; Построение информационной конструкции.

Отношения как основа построения структур. При обеих вариантах на рис. 1 и рис. 2 важное значение имеют отношения, которые необходимо выявить. Применение отношений при построении структуры вытекает из следующего.

Любая система или конструкция имеет структуру. Структура характеризуется наличием связей и частей. Поэтому формирование структуры объекта включает деление объекта на части и установление разных типов связей в этой совокупности. Любой объект или система взаимодействуют с внешней средой, поэтому связи делятся на две группы внешние и внутренние. Эти связи имеют разное качество: информационные, коммуникационные, функциональные и др. Основой формирования связей являются отношения. Существование отношений является необходимым, но не достаточным условием формирования связей и формирования структуры. Наличие отношений позволяет соотносить между собой части совокупности, которая изначально не описываются структурой. Выделение частей из совокупности и нахождение связей дает возможность формирования структуры.

Отношения в информационном поле можно рассматривать как некое информационное соответствие между элементами множества или совокупности. Эти соответствия можно делить на сильные и слабые. Слабое соответствие выражается отношением. Сильное соответствие выражается связью. Унитарные отношения описывают свойства частей или элементов. Бинарные отношения между частями совокупности отражают взаимность и приводят к построению связей. Отношения порядка в системе и задают иерархию в этой системе среди ее элементов и частей. Среди различных отношений в последнее время широко применяют и используют информационные отношения (Tsvetkov, 2015). Информационные отношения отражают прямые, косвенные, первичные и вторичные отношения между информационными моделями и их частями.

При информационном структурном моделировании возникают и решаются задачи, которые не решаются методами информационного статистического моделирования. Первое, что необходимо различать это структурная вложенность, которая структурой не является, и структура (рис. 3).

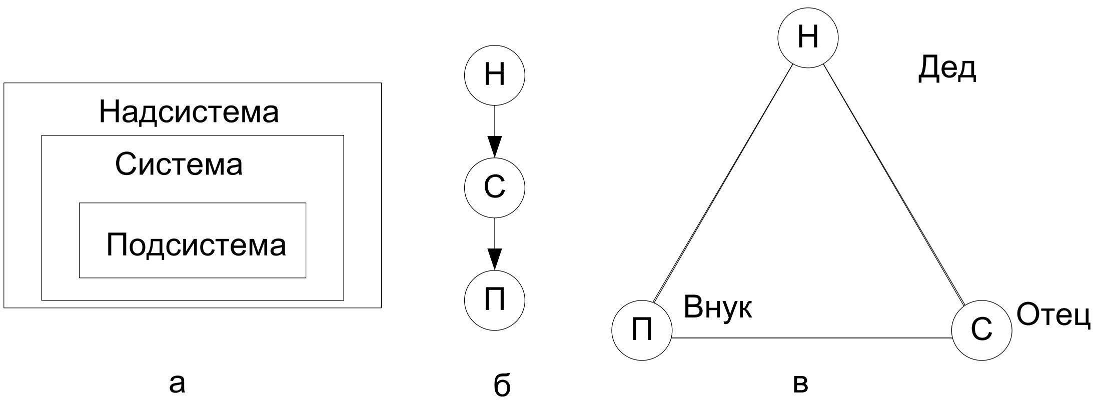

Рис. 3. Структурная вложенность а) и два типа структуры

Рис. 3 а) показывает схему структурной вложенности, которая является выражением системного подхода. Эта схема показывает факт наличия частей системы, но не задает связи между ними. На рис 3 показана надсистема (Н), система (С) и подсистема (П). На рис. 3 б) показана иерархическая структура этих компонент, которая является линейной. Иерархическая структура служит основой управления [13] в вооруженных силах и диктаторских режимах.

На рис. 3 в) показана тринитарная структура этих компонент, которая является нелинейной. Для наглядности приведены сопоставления: надсистема – дед, система - отец, подсистема – внук. На рис. 3 в) отношение Н-С и отношение С-П равнозначны. Это отношения отца к сыну. Но отношение Н-П деда и внука является дополнительным и отличается от отношений Н-С. Это отношение может задавать обратную связь и быть основой самоорганизации тринитарной системы. Три разных отношения формируют тринитарную структуру. В настоящее время это понятие широко используют: в теологии (SM T. R., 2007), в социологии (Grassl, 2013) и в философии. В технических науках и в области моделирования это понятие используют редко. Если отношение Н-П отсутствует, то тринитарная структура преобразуется в линейную иерархическую структуру.

4. Обсуждение

Современные подходы структурного моделирования ориентированы в основном на функциональные детерминированные методы или на статистические вероятностные методы. Информационный подход информационные единицы и информационные конструкции не применяют во многих методах структурного моделирования. Применение информационных единиц аналогично применению метода конечных элементов при структурном проектировании (De Borst et al., 2012). Это является косвенным подтверждением правильности информационного подхода. Термин структурное моделирование и особенно структурный анализ используется в психологии, социологии и связан с извлечением срытых переменных в бесструктурной эмпирической совокупности. В детерминированном моделировании чаще используют термин структурное проектирование. При построении структур предпочитают строить структуры по иерархическому принципу. Тринитарные структуры практически не используют при структурном моделировании, хотя они служат основой самоорганизующихся систем и нелинейных процессов. Информационное структурное моделирование создает возможность построения нелинейных структур. Понятие информационная конструкция также практически не используют во многих методах. В тоже время по определению основная функция информационной конструкции моделирование и отражение структуры объектов и процессов. Применение информационной конструкции должно упростить структурное моделирование.

5. Заключение

Информационное поле служит основой связи между разными эмпирическими данными. Оно задает информационные связи между первичными и вторичными данными, которые впоследствии могут быть описаны различными функциональными связями. Использование информационного поля в качестве концепции построения структуры является фундаментальным. Такая концепция задает информационный подход как основу для структурного моделирования.

Предварительным этапом структурного моделирования является формирование модели информационной ситуации. Информационная ситуация включает связи и отношения объекта с другими объектами и с частью информационного поля. Для моделирования структур при помощи статистического или детерминированного подходов эффективно использование информационной конструкции. Информационная конструкция является обобщенным описанием моделей, объектов, процессов или явлений. Информационная конструкция позволяет выявить ключевые взаимосвязи между различными факторами, чтобы проанализировать исследуемый процесс или технологию. Она позволяет использовать главные факторы для построения структуры исследуемого объекта, технологии или процесса. Информационная конструкция позволяет также строить нелинейные и тринитарные структуры, которые пока остаются за рамки исследований в области структурного моделирования. Перенос статистических методов структурного моделирования в область информационных технологий может существенно развить данное направление и способствовать обобщению и развитию теории структурного моделирования.

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