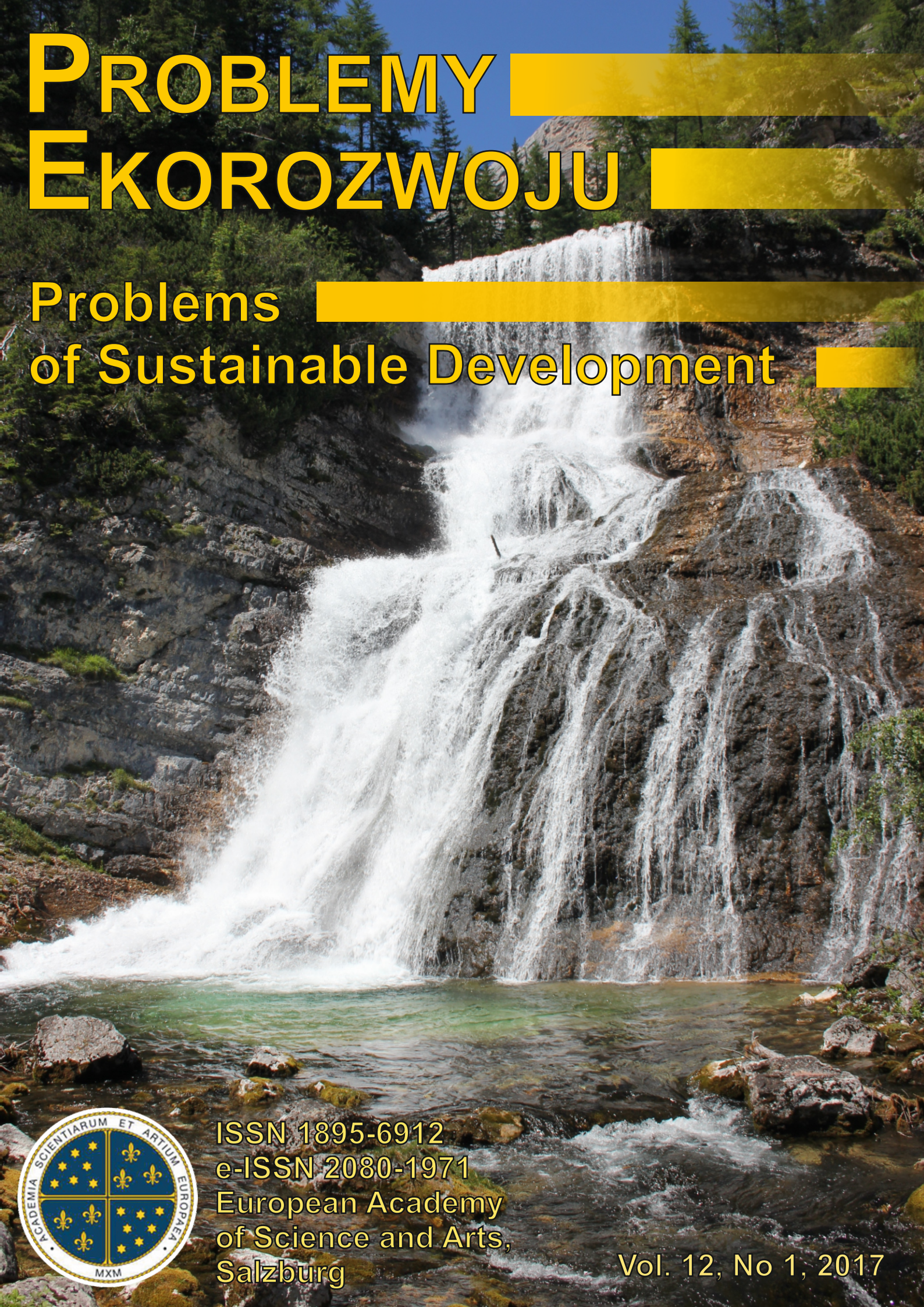
# PROBLEMY EKOROZWOJU

## Problems of Sustainable Development



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# PROBLEMS OF SUSTAINABLE DEVELOPMENT

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# PROBLEMY EKOROZWOJU

## PROBLEMS OF SUSTAINABLE DEVELOPMENT

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**PROBLEMY EKOROZWOJU – PROBLEMS OF SUSTAINABLE DEVELOPMENT**
**2017, vol. 12, no 1, 7-14**

# The Effect of Environmental Innovation on Employment Level: Evidence from China's Manufacturing Industries

# Wpływ innowacji ekologicznych na poziom zatrudnienia: przykład przemysłu w Chinach

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## Abstract
This paper examines the effect of environmental innovation on employment level, using an industry-level panel dataset for the 2001-2010 period in China. Empirical results show that environmental process innovation has a positive effect on employment, but with a time lag. Furthermore, the relationship between environmental innovation and employment is heterogeneous across *dirty* industries and *clean* industries in China. Based on the empirical result, this study derives some policy implications.

**Key words:** environmental innovation, employment, manufacturing industries, panel data

## Streszczenie
Artykuł dyskutuje wpływ innowacji środowiskowych na poziom zatrudnienia, w oparciu o bazę danych obejmującą lara 2001-2010, a odnoszącą się do Chin. Uzyskane rezultaty pokazują, że wprowadzanie ekologicznych innowacji ma pozytywny wpływ na zatrudnienie, jednak jest to widoczne dopiero w dłuższej perspektywie czasowej. Ponadto okazało się, że powiązania pomiędzy ekologicznymi innowacjami a zatrudnieniem są odmienne w odniesieniu do *brudnych* i *czystych* gałęzi przemysłu w Chinach. Przeprowadzone badania pozwalają na sformułowanie zaleceń na przyszłość.

**Słowa kluczowe:** innowacje ekologiczne, zatrudnienie, przemysł wytwórczy, bazy danych

## 1. Introduction

In recent decades, China has achieved a veritable economic miracle, but her rapid development of manufacturing industries leads to the deterioration of environment (Yu and Chen, 2015). China's environmental pollution is increasingly become an important issue both domestically and internationally. The rapid increase of many environmental problems calls for innovations that may reduce the environmental impact of economic activity, and therefore environmental innovation (EI) is portrayed to be one of the key approaches to solve environmental pollution. Due to increasing environmental regulations, public pressure and public scrutiny, many firms in China have adopted EI developments to attain competitiveness and environmental sustainability.

One of the topics commonly addressed during political debates concerns the question of how firms' transformations towards being green affect economic performance and employment (Rennings et al., 2004). Numerous contributions have tried to investigate the dynamics, characteristics and determinants of EI and their impact on economic systems and societies as a whole (Arundel and Kemp, 2011; Arundel et al., 2011; Beise and Rennings, 2005; Costantini and Mazzanti, 2012; Jaffe and Palmer, 1997; vanden Bergh et al., 2007; Wagner 2007). However, little attention has been paid to the consequences of EI on employment. The relationship is not particu-

larly well known and the views and impacts indeed spur ongoing debate (Kunapatarawong, 2016).

The main purpose of the paper is to analyze the effects of EI on employment, using China's manufacturing industries panel data. As the largest developing country, the increasing relevance of environmental issues for the Chinese economy, its employment problem, and its innovation structure make China an interesting context to investigate.

This study contributes to the literature in the following ways. First, most studies testing the relationship between EI and employment focus on the advanced economies, only a few expand the study to other settings. China is an excellent case for newly industrialized economies. This study examines whether EI triggers employment in China, which can add new evidence to this line of research by providing data from NIEs. Second, it tries to fill the gap by providing more empirical evidence about the relationship between EI and employment at industry level. Third, this study examines the effects of different types of EI on employment in the 37 two-digit manufacturing industries as well as distinguishes the effects of EI on employment between clean industries and dirty industries.

The remainder of this paper is organized as follows: section 2 gives a short review of the literature on EI and employment. Section 3 proposes the empirical models and describes the dataset. Section 4 displays the empirical estimates and discusses the results. Section 5 contains concluding remarks and policy implications.

## 2. Literature review

### *2.1. The definition of environmental innovation*

The terms eco-innovation, EI and green innovation have been used synonymously (Tietze et al., 2011). Following the Measuring Eco-Innovation (MEI) project, we adopt the definition of EI as following: *the production, assimilation or exploitation of a product, production process, service or management or business methods that is novel to the firm [or organization] and which results, throughout its life cycle, in a reduction of environmental risk, pollution and pollution and other negative impacts of resources use (including energy use) compared to relevant alternatives* (Kemp and Pontoglio,2007, p.10). This definition includes innovations that are not necessarily new to the world but are at least new to the organization adopting them, as the Oslo Manual on innovation suggests (OECD, 2005), so that not only new environmental technologies, but also any new/improved product or process or service has to be accounted for. Furthermore, this includes also *unintended* innovations when they result in environmental improvements as well.

### *2.2. Environmental innovation and employment*

Most researchers pay more attention to the effects of standard innovation on employment. A detailed tailed overview of the existing literature is given by Chennells and Van Reenen (2002). Entorf and Pohlmeier (1990) and Zimmerman (1991) analyze German micro data. Entorf and Pohlmeier (1990) find a positive effect for product innovations, while process innovations show no significant effects. Zimmerman (1991) concludes that technological progress was important for the employment decrease in 1980, i.e. he finds a negative effect of innovation. But the definition of innovation he uses refers to a question asking explicitly for the implementation of labor-saving technological progress. Blanchflower and Burgess (1998), however, find a positive relation between process innovation and employment growth using innovation surveys from the UK in 1990 and Australia in 1989/1990. Lachenmaier and Rottmann (2007) use a static panel approach and also find significantly positive effects for both types of innovation.

In recent years, manufacturing industries have been pressured to adopt EI to achieve greening goals alongside economic goals. Despite its importance, the empirical evidences from advanced economy about the effects of EI on employment at the macroeconomic level are rare (Pfeiffer and Rennings, 2001; Rennings et al., 2004) and puzzled. On the one hand, environmental regulations have created many new firms and industries, such as those of *environmental industry* (Harrison et al., 2014). In this respect, the impact of EI on employment has been positive. On the other hand, EI, particularly cleaner productions, reduce demand for energy and/or material of certain industries. This reduces labor demand in these affected industries where material and energy demand is reduced (Pfeiffer and Rennings, 2001); particularly for certain workers who work with obsolete and so called dirty material or technologies. At the same time, there will be labor demand increase in industries with cleaner technologies. The net effect at the industry-level is therefore uncertain as EI reduces labor demand in some industries, while increases labor demand in other industries. Horbach (2010) and Gagliardi et al. (2016) find positive effects for EI while Licht and Peters (2013) observe positive but not significant differences between environmental and non-environmental product innovations. Kunapatarawong and Martínez-Ros (2016) find a positive relationship between EI and employment.

Another strand of literature focuses more specifically on the effects of different types of EI on employment. Their expected outcomes on employment are different. From a theoretical point of view, product innovations are expected to have a positive, demand-related, effect (Harrison et al., 2014) while process innovations to a negative effect due to increased labour productivity (Cainelli et al., 2011). Horbach and Rennings(2013) show that environmental product innovation does not trigger employment, but environmental process innovation does,

particularly for environmental process innovations that lead to material and energy savings. Rennings et al., (2004) find that environmental product innovations have a positive effect on the probability of an employment increase, consistent with his prior work in Rennings and Zwick (2002). The shift from end-of-pipe technologies to cleaner production creates jobs (Rennings and Zwick, 2002).

Reviewing the literature, the impact of EI on employment has proved to be controversial. In fact, two points are worth examining with regard to the EI-employment nexus. First, most studies are based on the predominant U.S. and EU samples, while the relationship between EI and employment at industry level in developing countries like China has not been investigated. Second, the effects of different types of EI on employment distinguished between clean industries and dirty industries have not been adequately examined.

## 3. Empirical model and data sources

### *3.1. Econometric model*

To examine the relationship between EI and employment, we follow the existing literature (Kunapatarawong and Martínez-Ros, 2016) in estimating a reduced-form regression, which takes the form:

$$Employment_{it} = \beta_0 + \beta_1 EI_{it-1} + \beta_2 X_{it-1} + \mu_i + \varepsilon_{it}$$

where *i* denotes industries and *t* years. *Employment* is a measure of the total number of employees in an industry. *EI* is a measure of environmental innovation in an industry. The following section discusses in detail the various alternative proxy variables used. $X_{it}$ is a set of control variables. The terms $\mu_i$ and $\varepsilon_{it}$ represent the unobserved industry-specific heterogeneity and white noise, respectively.

### *3.2. Dependent variable*

The dependent variable is *Employment*. Referring to prior scholars (i.e. Harrison et al., 2014; Horbach and Rennings,2013; Lachenmaier and Rottmann, 2011; Rennings et al., 2004) this paper employs log of employees as measures of *Employment*. The paper aims to study the relationship between EI and employment level.

### *3.3. Explanatory variable*

According to Hemmelskamp (1997), our independent variable, EI can be subdivided into environmental product innovation（$EI_{product}$） and environmental process innovation($EI_{process}$). $EI_{product}$ is measured by the ratio of energy consumption to new product output in an industry. Referring to Copeland and Taylor (2003), we use pollution discharge intensity as the proxy variable of environmental technology, specifically, $EI_{process}$ is measured by the ratio of industrial waste water discharged to gross industrial output value.

### *3.4. Control variables*

To control for industry characteristics, we include a variety of control variables which have been shown elsewhere to be important determinants of industrial employment.

Firstly, we control for market characteristics by including industrial growth (*Sales growth*) per industry as a determinant of employment. A growing market provides incentives for firms, and thus increases employment. We measure *Sales growth* as the growth rate of industry sales. We deflate growth in nominal sales with consumer price index.

Secondly, we include industry value added (*Value Added*) which is measured by value added per industry, is the long-standing concern factor on influencing industry employment. Generally, a larger industry tends to employ more employees.

Thirdly, capital intensity(*Capi*) serves as an alternative determinant that might negatively correlate with employment, because capital-intensive industries generally need more capital investment and less labor demand compared to other industries with development of new technologies or processes.

Rennings et al.,(2004) claim firms first make decisions to invest in environmental innovation, and then employment adjustments during a second stage. Following their specification, EI enters the equation in the form of a 1-year lagged. Moreover, to avoid the endogenous problem, all other control variables are also specified in 1-year lagged forms.

### *3.5. Data sources*

This paper selects the panel data of 37 two-digit manufacturing industries under China's industrial classification system from 2001-2010. Three manufacturing industries including Craftwork and other manufactures, Mining of Other Ores and Utilization of Waste Resources are omitted due to missing data, so we exclude the three manufacturing industries from the sample[1] (See Appendix: Table 6 for 37 two-digit industry category in China). The main dataset for this research comes from the China Industry Economy Statistical Yearbooks, the China Science and Technology Statistical Yearbooks and the China Environment Statistical Yearbooks. We deflate the data using industry-specific price deflators to obtain real series. Table 1 summarizes the definitions and summary statistics of all variables. All nominal variables are deflated into real variables by using manufacturing intermediate input-output price indices for the year 2001.

## 4. Empirical results

### *4.1 Correlation analysis*

The correlation analysis in Table 2 shows the Variance Inflation Factor (VIF) of all explanatory va-

[1] See Appendix for 37 two-digit industry category in China.

Table 1. Definitions and summary statistics of all variables.

| Varible | Denifitions | Mean | SD |
|---|---|---|---|
| *Employment* | The total number of employees in an industry(10 thousand person) | 107.4864 | 102.2092 |
| *Energy consumption* | Million tons of standard coal | 4492.197 | 8415.612 |
| *New product* | Output value of new products (RMB￥ 100 million） | 944.2675 | 2110.36 |
| $EI_{product}$ | The ratio of energy consumption to new product output in an industry | 80.91212 | 485.8611 |
| *Waste water discharge* | Total volume of industrial waste water discharge（Ton 10 thousand） | 54789.6 | 86364.68 |
| *Value Added* | Gross industrial output value (RMB￥ 100 million） | 5737.669 | 8068.133 |
| $EI_{process}$ | The ratio of industrial waste water discharged to gross industrial output value | 2.112202 | 3.976517 |
| *Sales growth* | Growth rate of industry sales (%) | 0.349775 | 1.417504 |
| *Capi* | Capital intensity: ratio of capital to labor employed (RMB￥ thousand/person) | 203283.3 | 213157.9 |

Note: The summary statistics reported are reported by the pooling data of 34 China's manufacturing industries for the period of 2001-2010.

Table 2. Pearson correlation matrix

a) Model for the effect of $EI_{product}$ on employment

| Variable | VIF | 1/VIF |
|---|---|---|
| $EI_{product}$ | 1.03 | 0.973083 |
| *Value Added* | 1.17 | 0.856494 |
| *Capi* | 1.17 | 0.857225 |
| *Sales growth* | 1.00 | 0.998173 |
| Mean VIF | 1.09 | |

b) Model for the effect of $EI_{process}$ on employment

| Variable | VIF | 1/VIF |
|---|---|---|
| $EI_{product}$ | 1.05 | 0.95275 |
| *Value Added* | 1.20 | 0.832596 |
| *Capi* | 1.15 | 0.869616 |
| *Sales growth* | 1.00 | 0.997505 |
| Mean VIF | 1.10 | |

Table 3. Effects of environmental innovations on employment of all industries

| Variable | Model 1 (RE) | Model 2 (RE) |
|---|---|---|
| $EI_{product}$ | -0.0047844* (-1.68) | |
| $EI_{process}$ | | 1.056749* (1.81) |
| *Value Added* | 0.0076221*** (19.79) | 0.007488*** (19.29) |
| *Sales growth* | 1.870541** (2.19) | 1.968815** (2.30) |
| *Capi* | -0.000151*** (-9.00) | -0.00014*** (-8.59) |
| *Cons* | 119.2077*** (10.51) | 116.2789*** (10.26) |
| Industry dummy | Yes | Yes |
| Time dummy | Yes | Yes |
| *R*-square | 0.7405 | 0.7422 |
| Hausman test | 1.35 | 1.39 |
| Observations | 324 | 324 |

*Note*: Industry and year effects are included in all regressions. z statistics are in parentheses. R-squared defined as the squared correlation between the actual and predicted value of the dependent variable. All variables are in levels. *Significance at the 10% levels, **Significance at the 5% levels, ***Significance at the 1% levels.

riables and control variables in Pearson correlation matrix are less than 10, implying that the econometric models do not exist multicollinearity problems.

*4.2 Baseline regression results*

Table 3 reports the results obtained using linear panel data models to estimate econometric model, testing the effects of EI on employment for 37 two-digit manufacturing industries. Use of a *within* panel estimator, a fixed effect (FE) or random effect (RE) technique, to eliminate the individual effect is a standard estimation method in the panel dada model. As all Hausman test statistics are not significant at the 1% statistical level, suggesting that the random effect model is more appropriate, we only display the estimates of the random effect model.

Controlling for the time- and industry-specific effects, model (1) and model (2) are the main estimating results based on the relationship between environmental product innovation($EI_{product}$) and employment, and between environmental process innovation($EI_{process}$) and employment in China respectively. The estimated coefficient for environmental process innovation is positive and statistically significant at the 10% statistical level, suggesting that employment of all industries would be triggered by about 1% in case of a 1% increase in environmental process innovation. However, the estimated coefficient for environmental product innovation is negative and statistically significant at the 10%, moreover, the coefficient is -0.0047844; it implies that negative effect induced by environmental product innovation is not very significant. The result is consistent with findings by Horbach and Rennings (2013), that green product innovation does not trigger employment, but green process innovation does.

Why can environmental process innovation rather than environmental product innovation lead to a higher employment in manufacturing industries in China? The intuitive explanation is that environmental process innovations that induce material and energy savings can improve the competitiveness of firms, this has a positive effect on demand and thus also increases employment (Horbach and Rennings, 2013). While environmental product innovations may cause a monopolistic position leading to a reduction of output (Hall et al. 2006), thus the effect for employment is negative.

As for the influences of other control variables, the results obtained overall are consistent with theoretical estimations. An industry with much more *Value Added* and a higher sales growth rate tends to induce more employment, certis paribus. However, there are significantly negative effects of *Capi* on employment.

*4.3 Industry heterogeneity*

Baseline regression results considered thus far assume that the slope coefficients $\beta$ in baseline regression is constant across industries. This assumption may be inappropriate. In particular, industries may be heterogeneous in their response to changes in employment to EI. This subsection further examines the impact of EI on employment in dirty and clean industries[2], using linear panel data models to estimate econometric model respectively.

*4.3.1. Effects of environmental innovation on employment of dirty industries*

Table 4 displays the estimate results of the effects of EI on employment in dirty industries. We can only show the results obtained using the fixed effect of panel data model, as all the Hausman tests reject the null hypothesis at the 1% statistical level.

Controlling for the time- and industry-specific effects, the coefficient of environmental process innovation in model (2) is positive and significant at the 5% level, but the coefficient of environmental product innovation is negative and insignificant in model (1), implying that environmental process innovation can promote employment in dirty industries in China, and environmental product innovation does not. The possible reason is that introduction of end-of-pipe measures may require additional staff as firm implement environmental process innovation in dirty industries.

*4.3.2. Effects of environmental innovation on employment of clean industries*

Table 5 shows the estimate results of the effects of EI on employment in clean industries. The Hausman test shows that the fixed effect model is more appropriate for model (1), while random effect model is more appropriate for model (2).

Are the effects of EI on the employment of clean industries the same as that of dirty industry? Controlling for the time- and industry-specific effects also, interestingly, we find the estimated coefficient of environmental process innovation in model (2) is positive but not statistically significant, however, the estimated coefficient of environmental product innovation in model (1) is negative and significant at the 1% level, employment would be decreased by about 0.03% in case of a 1% increase in environmental product innovation in clean industries in China, implying that environmental product innovation has a negative effect on employment in clean industries. This might be because substitution of more environmentally friendly products for highly-polluting products (product innovation accompanied by product innovation) arising from environmental product innovation brings about a decrease in employment demand in clean industries..

[2] See Appendix for dirty and clean industries in China.

Table 4. Effects of environmental innovations on employment of dirty industries

| Variable | Model 1 (RE) | Model 2 (RE) |
|---|---|---|
| $EI_{product}$ | -0.0011015 (-0.68) | |
| $EI_{process}$ | | 0.8136084** (2.23) |
| *Value Added* | 0.0023008*** (6.83) | 0.0021168*** (6.22) |
| *Sales growth* | 0.3675782 (0.77) | 0.4794257 (1.02) |
| *Capi* | -0.0000226* (-1.88) | -0.0000182 (-1.56) |
| *Cons* | 113.1165*** (5.91) | 112.0016*** (5.89) |
| Industry dummy | Yes | Yes |
| Time dummy | Yes | Yes |
| *R*-square | 0.7144 | 0.7264 |
| Hausman test | 0.92 | 1.05 |
| Observations | 153 | 153 |

*Note*: Industry and year effects are included in all regressions. z statistics are in parentheses. R-squared defined as the squared correlation between the actual and predicted value of the dependent variable. All variables are in levels. *Significance at the 10% levels, **Significance at the 5% levels, ***Significance at the 1% levels.

Table 5. Effects of environmental innovation on employment of clean industries

| Variable | Model 1 (RE) | Model 2 (FE) |
|---|---|---|
| $EI_{product}$ | -0.0307137*** (-3.20) | |
| $EI_{process}$ | | 4.60094 (1.61) |
| *Value Added* | 0.0109464*** (25.54) | 0.0104771*** (23.47) |
| *Sales growth* | 3.699714 (1.02) | 3.635233 (0.98) |
| *Capi* | -0.0002046*** (-4.81) | -0.0001119*** (-3.41) |
| *Cons* | 103.592*** (7.70) | 88.48386*** (11.05) |
| Industry dummy | Yes | Yes |
| Time dummy | Yes | Yes |
| *R*-square | 0.8995 | 0.8940 |
| Hausman test | 2.85 | 6.58 |
| Observations | 171 | 171 |

## Concluding and policy implications

This study investigates whether EI would trigger employment in China. On the basis of a panel dataset of 37 manufacturing industries during the period 2001-2010, and we derive interesting and important findings. Baseline regression results show environmental process innovation has a positive effect on employment, while environmental product innovation does not. The result is consistent with findings by Horbach and Rennings (2013). Furthermore, we also identify that the relationship between EI and employment is heterogeneous across manufacturing industries in China.

Results show that environmental process innovation can trigger employment in dirty industries significantly, and the employment induced effect for clean industries is not significant. Nonetheless, environmental product innovation has a significant negative effect on employment in clean industries, while exhibits no significant negative influence on employment in dirty industries.

From the above analysis, this study derives two policy implications. First, EI helps manufacturing industries not only in terms of reducing resource and public scrutiny, but also in term of relationship with employment. Moreover, employment effects of different environmental innovation fields is different, especially environmental process innovation can induce employment significantly in manufacturing industry. Thus, to increase employment, the Chinese government should adjust its policy for enhancing EI in manufacturing industry, in particular, should place more emphasis on environmental process innovation. Second, as employment in dirty industries can be promoted by environmental process innovation in China, to achieve a win-win situation in which the dirty industries can simultaneously attain both goals of a reducing pollution and creating more jobs, more environmental process innovation should be adopted in dirty industries of China. In addition, given the significantly negative effect on employment brought by environmental product innovation in clean industries, the Chinese government should take measures to decrease the unfavorable influences of environmental product innovation on employment in clean industries to the most extent.

This work has several limitations that should be taken into account. To the best our knowledge, China has no nationwide statistics on environmental patent. Besides, it is very difficult to compile industry-level environmental patent data because of difference in industry and patent classifications. This study measure environmental product innovation and process innovation only by using the ratio of energy consumption to new product output and the ratio of industrial waste water discharged to gross industrial output value respectively. Moreover, empirical work on the EI-employment relationship can be influenced by a wealth of different factors, however, owing to

the limitation of data source, only *Value added*, *Sales growth* and *Capi* are used as control variables in this study. Furthermore, we only provide industry-level analysis. It would be interesting to conduct a similar study for China using a firm level dataset to examine the robustness of our results.

**Appendix A. Composition of industry categories**

Table 1. Composition of industry categories in China

| SIC code | Two-digit category |
|---|---|
| 06 | Coal mining and dressing |
| 07 | Extraction of Petroleum and Natural gas |
| 08 | Ferrous metal mining & dressing |
| 09 | Non-ferrous metal ores mining and dressing |
| 10 | Mining and Processing of Nonmetal Ores |
| 11 | Mining of Other Ores |
| 13 | Agriculture and sideline foods processing |
| 14 | Food production |
| 15 | Beverage production |
| 16 | Tobacco products processing |
| 17 | Textile industry |
| 18 | Clothes, shoes and hat manufacture |
| 19 | Leather, furs, down and related products |
| 20 | Timber processing, bamboo, cane, palm fiber and straw products |
| 21 | Furniture manufacturing |
| 22 | Papermaking and paper products |
| 23 | Printing and record medium reproduction |
| 24 | Cultural, educational and sports articles production |
| 25 | Petroleum processing, coking and nuclear fuel processing |
| 26 | Raw chemical material and chemical products |
| 27 | Medical and pharmaceutical products |
| 28 | Chemical fiber |
| 29 | Rubber products |
| 30 | Plastic products |
| 31 | Nonmetal mineral products |
| 32 | Smelting & pressing of ferrous metals |
| 33 | Smelting & pressing of non-ferrous metals |
| 34 | Metal products |
| 35 | Ordinary machinery manufacturing |
| 36 | Specialty equipment manufacturing |
| 37 | Transport equipment and manufacturing |
| 39 | Electric machines and apparatuses manufacturing |
| 40 | Communication equipment, computers, and other electronic equipment |
| 41 | Instruments, meters, cultural and office machinery manufacture |
| 42 | Craftwork and other manufactures |
| 43 | Utilization of Waste Resources |
| 44 | Electricity and heating production and supply |
| 45 | Fuel gas production and supply |
| 46 | Water production and supply |

Note: Industry *Mining of Other Ores* (SIC code 11) , *Utilization of Waste Resources* (SIC code 43) and *Craftwork and other manufactures* (SIC code 42) are omitted due to missing data.

We partition industries into dirty and clean industries with respect to the level of pollution and toxin each industry is discharging into the environment, as shown in Table A2.

Table 2. Industry classification: dirty and clean in China

| Dirty industries | |
|---|---|
| SCI Code | Two-digit category |
| 6 | Coal mining and dressing |
| 7 | Extraction of Petroleum and Natural gas |
| 8 | Ferrous metal mining & dressing |
| 9 | Non-ferrous metal ores mining and dressing |
| 10 | Mining and Processing of Nonmetal Ores |
| 22 | Papermaking and paper products |
| 25 | Petroleum processing, coking and nuclear fuel processing |
| 26 | Raw chemical material and chemical products |
| 27 | Medical and pharmaceutical products |
| 28 | Chemical fiber |
| 29 | Rubber products |
| 30 | Plastic products |
| 31 | Nonmetal mineral products |
| 32 | Smelting & pressing of ferrous metals |
| 33 | Smelting & pressing of non-ferrous metals |
| 44 | Electricity and heating production and supply |
| 45 | Fuel gas production and supply |
| Clean industries | |
| SCI Code | Two-digit category |
| 13 | Agriculture and sideline foods processing |
| 14 | Food production |
| 15 | Beverage production |
| 16 | Tobacco products processing |
| 17 | Textile industry |
| 18 | Clothes, shoes and hat manufacture |
| 19 | Leather, furs, down and related products |
| 20 | Timber processing, bamboo, cane, palm fiber and straw products |
| 21 | Furniture manufacturing |
| 23 | Printing and record medium reproduction |
| 24 | Cultural, educational and sports articles production |
| 34 | Metal products |
| 35 | Ordinary machinery manufacturing |
| 36 | Specialty equipment manufacturing |
| 37 | Transport equipment and manufacturing |
| 39 | Electric machines and apparatuses manufacturing |
| 40 | Communication equipment, computers, and other electronic equipment |
| 41 | Instruments, meters, cultural and office machinery manufacture |
| 46 | Water production and supply |

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## References

1. ARUNDEL A., KANERVA M., KEMP R., 2011, *Integrated Innovation Policy for an Integrated Problem: Addressing Climate Change,*

*Resource Scarcity and Demographic Change to 2030*. PRO INNO Europe: INNO-Grips II report, European Commission, , Brussels.
2. ARUNDEL A., KEMP R., 2011, *Measuring eco-innovation,* UNU-MERIT Working Paper Series No. 2009-017, Maastricht.
3. BEISE M., RENNINGS K., 2005, Lead markets and regulation: a framework for analyzing the international diffusion of environmental innovations, in: *Ecological Economics* 52, p. 5-17.
4. CAINELLI G., MAZZANTI M., MONTRESOR S., 2012, Environmental innovations, local networks and internationalization. in: *Industry and Innovation* 19 (8), p. 697-734.
5. COPELAND B.R., TAYLOR M.S., 2003, *Trade and the Environment: Theory and Evidence,* Princeton University Press, Princenton.
6. COSTANTINI V., MAZZANTI M., 2012, On the green and innovative side of trade competitiveness? The impact of environmental policies and innovation on EU exports, in: *Research Policy* 41, p. 132-153.
7. GAGLIARDI L., MARIN G., MIRIELLO C., 2016, The greener the better? Job creation effects of environmentally-friendly technological change. in: *Industrial and Corporate Change* 1, p. 1-29.
8. KEMP R., PEARSON P., 2007, *Final report of the MEI project measuring eco-innovation,* MEI Project number 044513. Deliverable 15.
9. HALL B.H., LOTTI F., MAIRESSE J., 2006, *Employment, Innovation and Productivity: Evidence from Italian Microdata,* The Institute for Fiscal Studies. Working Paper 24/2006, London.
10. HARRISON, R., JAUMANDREU BALANZO J., MAIRESSE J., PETERS B., 2014, Does innovation stimulate employment? A firm-level analysis using comparable micro-data from four European countries, in: *International Journal of Industrial Organization* 35, p. 29-43.
11. HEMMELSKAMP J., 1997, Environmental Policy Instruments and their Effects on Innovation, in: *European Planning Studies* 2, p. 177-194.
12. HORBACH J., 2010, The impact of innovations activities on employment in the environmental sector-empirical results for Germany at the firm level, in: *Journal of Economics and Statistics* 230(4), P. 403-419.
13. HORBACH J., RENNINGS K., 2013, Environmental innovation and employment dynamics in different technology fields-an analysis based on the German Community Innovation Survey 2009. in: *Journal of Clean Production* 57, p. 158-165.
14. JAFFE A.B., PALMER K., 1997, Environmental regulation and innovation: a panel data study, in: *The Review of Economics and Statistics* 79, p. 610-619.
15. KUUAPATARAWONG R., MARTINEZ-ROS E., 2016, Towards green growth: How does green innovation affect employment? in: *Research Policy* 45, p. 1218-1232.
16. LACHENMAIER S., ROTTMANN H., 2011, Effects of innovation on employment: a dynamic panel analysis, in: *International Journal of Industry Organization* 29, p. 210-220.
17. LICHT G., B PETERS., 2013, *The impact of green innovation on employment growth in Europe,* WWW for Europe, Working Paper No 50.
18. OECD., 2005, *The measurement of scientific and technological activities. Proposed Guidelines for Collecting and Interpreting Technological Innovation*, European Commission and Eurostat.
19. PEIFFER F., RENNINGS K., 2001, Employment impacts of cleaner production-evidence from a German study using case studies and surveys, in: *Business Strategy Environment* 10, p. 161-175.
20. PORTER M.E., VAN DER LINDE C., 1995, Toward a new conception of the environment-competitiveness relationship, in: *Journal of Economics Perspectives* 9 (4), p. 97-118.
21. PORTER M.E., 1991, America's green strategy, in: *Scientific American* 264 (4), p. 168.
22. RENNINGS K., ZIEGLER A., ZWICK T., 2004, The effect of environmental innovations on employment changes: an econometric analysis, in: *Business Strategy and Environment* 13, p. 374-387.
23. RENNINGS K., ZWICK T., 2002, Employment impact of cleaner production on the firm level: empirical evidence from a survey in five European countries. In: *International Journal of Innovation Management* 6, p. 319-342.
24. TIETZ F., SCHIEDERIG T., HERSTATT C., 2011, *What is green innovation? A quantitative literature review,* Paper Presented at the XXII ISPIM Conference.
25. VAN DEN BERGH J.C.J.M., FABER A., IDENBURG A., OOSTERHUIS F., 2007, *Evolutionary Economics and Environmental Policy, Survival of the Greenest*, Elgar, Cheltenham.
26. WAGNER M., 2007, On the relationship between environmental management, environmental innovation and patenting: evidence from German manufacturing firms, in: *Research Policy* 36, p. 1587-1602.
27. Wei Y., QIANG CH., 2015, Environmental regulations and industrial performance: evidence from the revision of Water Pollution Prevention and Control Law in China, in: *Problemy Ekorozwoju/ Problems of Sustainable Development* vol. 10, no 1, p. 41-48.

**PROBLEMY EKOROZWOJU – PROBLEMS OF SUSTAINABLE DEVELOPMENT**
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# Climatic Migrations – Consequences of Upsetting Environmental Balance and a of Flaws in Human Protection by International Law

# Migracje klimatyczne – konsekwencje naruszenia równowagi ekologicznej i przejaw niedoskonałości prawnomiędzynarodowej ochrony człowieka

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## Abstract

Climate changes, natural disasters and other problems caused by reckless or irresponsible human behaviour have resulted in a larger number of refugees than wars and conflicts. Their number is increasing and the trend is unlikely to reverse. Before our eyes, refugees have become the most visible consequence of the climate changes taking place on Earth, along with excessive exploitation of resources and unsustainable use and destruction of aquatic and land ecosystems, mainly agricultural land and forests. Therefore, it is becoming necessary to make oneself and others aware that the massive influx of people – mainly from Asia and Africa – is a signal of the extent of degradation of the living environment and of ecological imbalance in the areas where they previously lived. It is also becoming important to make the world of politics and the international community aware of the changes and of the need to develop plans of action and to take appropriate (if possible) preventive and corrective measures.

**Key words:** climate-induced migrations, environmental crisis, climate changes, unsustainable development, human rights

## Streszczenie

Zmiany klimatyczne, katastrofy naturalne i te powodowane nieostrożnością lub nieodpowiedzialnością człowieka, są przyczyną większej liczny uchodźców niż toczące się wojny i konflikty. Ich liczba ponadto ciągle wzrasta i nie zanosi się na odwrócenie tego trendu. Uchodźcy na naszych oczach stali się już najbardziej widoczną konsekwencją zachodzących zmian klimatycznych na Ziemi, ale też nadmiernej eksploatacji dóbr i niezrównoważonego wykorzystywania i niszczenia ekosystemów wodnych i lądowych, głównie rolniczych i leśnych. Koniecznością zatem staje się uświadomienie sobie i innym, że rzesze napływających ludzi – głównie z obszarów Azji i Afryki – są sygnałem i probierzem stopnia degradacji środowiska życia i naruszenia równowagi ekologicznej na terenach dotychczas przez nich zamieszkiwanych. Ważnym zadaniem staje się uwrażliwianie świata polityki i społeczności międzynarodowej na zmiany, na konieczność opracowania planów działania i przedsięwzięcia stosownych środków (na ile to możliwe) zaradczych i naprawczych.

**Słowa kluczowe:** migracje klimatyczne, kryzys ekologiczny, zmiany klimatyczne, niezrównoważony rozwój, prawa człowieka

### Introduction

The world of science and politics has been paying much more attention now than it has in the past to climate change and to natural phenomena which affect human life and international relations. This is worth closer examination, since migrations are a part of human history. Numerous explanation of the phe-

nomenon have been offered in sociology, economics and politics. The latest observations have led to focusing attention on environmentally induced migration (EIM). What are their characteristic features and how can they be defined?

From a concept-related point of view, there are two types of EIM. First, these are sudden events and natural disasters. They can include floods, tsunamis, earthquakes, cyclones, forest fires, volcano eruptions, as well as other, incidental or periodical phenomena which force people to leave their place of life and work. On the other hand, they can include slow changes which take place in the environment, which at first make further life difficult, and then impossible. This category includes processes which lead to erosion, deforestation, turning land into steppe or desert, water, air and soil pollution, salinisation, irregular precipitation, increased water level, etc. It is difficult to make such migrations concrete and defined because of the variety of causes, duration, the vastness of the geographic area in which they occur and a multitude of accompanying and secondary factors which affect people's decisions to leave their place of residence. Moreover, they can be forced or voluntary. For this reason, they are usually referred to as (multi-factorial) climate-induced/environmental migrations, because they are not directly caused by other people, as is the case with political or economic migrations.

In the case of slow environmental changes, migrants do not usually associate the need to take up a journey and/or to change a way of life with transformations that are taking place in their surroundings. They tend to see their migrations as caused by economic or social reasons. However, more detailed analyses show that, in most cases, poverty and insecurity (mainly related to food) is caused by a devastated natural environment. It can be noted that environmental factors are an indirect cause of migration by mixing together with other factors, if only socioeconomic ones. This proves the need for more detailed studies of the environment in countries where climate changes are the most intensive in order to explore their mechanism, dynamism, to forecast their effects and the possibility of implementing preventive programmes and measures.

**Defining the issue**

Migration is a process which takes place in time and space, it has always been people's response to unacceptable changes in the environment. They also imply a certain form of continuous or periodic displacement of individuals, family groups or whole communities, who take up their journeys in order to avoid drastic situations and to seek better living conditions. Periodical or incidental, targeted or improvised, they have saved people's lives in the face of danger brought about by natural or man-made disasters.

Mass displacements have usually taken place within one country, sometimes accelerating or amplifying environmental effects on the environment of such phenomena, as an increase in population density and increased exploitation of the host land. All of these effects were totally ignored until recently. The accompanying processes of globalisation and urbanisation have only intensified them.

What is the direction that the research should take before specific preventive and regulatory measures are implemented? It is beyond doubt that it is a serious limitation that there is no widely accepted definition of climate-induced migration and migrants. Partly because it is a new issue, but also because it is very complicated - one might say: interdisciplinary. This makes estimation of the scale and effects of the phenomenon considerably more difficult. Therefore, the situation is very complex, especially from the point of view of the functioning and potential of target countries, where the reasons for an influx of considerable numbers of climate-induced migrants are usually perceived in a more relative manner. For this and other reasons, especially those induced by climate changes, examination of migrations requires a broader perspective and consideration of all (environmental and other) factors and their interrelations, because all of them together, in different proportions, affect decisions to leave home.

The lack of a clear definition results in their unregulated status in international law, especially when they cross the borders of their own countries. Considering their previous and current status, they are sometimes classified as *climate-induced refugees*. Here another issue originates, because neither the *1951 Geneva Convention* (A) nor the *1967 Protocol* apply to such people because of too far-reaching environmental (climate) changes. In the present situation, climate-induced migrants have to take into consideration a certain form of legal discrimination, marginalisation, lack of material and economic support and even making their assimilation difficult.

So how can this state of things be reconciled with such a quantifier as an effective legal system and respect for human rights, which lie at the foundation of the desired type of development (called *sustainable*) and can it be thus termed with all the inequality of opportunities of all entities who work for it? Or to put it differently: what to do to make this development real? The need to combine development with sustainability is a relatively new task and one which has been examined only superficially. Sustainable development should be understood to denote progress which satisfies the needs of the present generation without adversely affecting the developmental opportunities and quality of life for future generations. So it should consist in integration of the economy, environment, inter- and intra-generation fairness, joint but diverse cooperation of the international community, elimination of areas of poverty,

reducing and eliminating unsustainable models of production and consumption, participation in decision-making processes and access to legal and administrative information, responsibility, etc. (Kośmicki, Pieńkowski, 2013). The factors under examination include the primary environmental causes, *attractiveness* and the effect on migration of economic and social features of the target place. As of today – mainly because of the lack and difficulty in gathering relevant data – it is not possible to separate climate-induced and environmental migration/migrants from migration and migrants who take a decision only (or largely) under pressure of economic and political factors. This is easily observable in Europe today, where numerous immigrants come from the Middle East and North Africa (Sitek, 2016). For the time being, the huge volume of news from all over the world suppresses information about climate-induced and environmental migration. This term denotes people who have left their homes as a result of irreversible damage caused by sudden climate changes which have forced them to seek a new place where they would be sure to survive, if only at a basic level. Following the news on a day-to-day basis gives one an opportunity to find out whether, how, and to what extent this is a responsibility of individual countries, types of economy and which of the effects of unsustainable development result in climate changes and phenomena which destroy or considerably hinder life in other parts of the globe.

The knowledge of the importance of what is going on is still limited despite its topicality. In consequence, analyses and data are rather superficial, even in documents which deal with the issue (C). Therefore, it is an open issue which should be given an appropriate rank and importance in order to protect and save people and things which can still be saved. However, it does not concern destructive issues themselves. Its importance stems from the fact that it is man who is the principal protagonist. Despite their undefined legal and international status, climate-induced migrants are a part of a phenomenon whose intensity is increasing. They are, above all, victims of natural disasters, whom the international community should provide with dual support: a sort of *external* support by protecting ecosystems which comprise the global ecosystem, and *direct* support, i.e. organising and providing concrete help to people who inhabit them – assistance which helps to maintain and implement (and restore – if this is required) a sustainable local economy.

Environmental disasters are events with (usually) serious, both short-term and long-term consequences; they shatter the lives of people who inhabit the affected area, they destroy previously established relations between components of biotopes and ecosystems. But primarily they make the environment so dangerous that it is a threat to the lives of people who live there. What seems to be the most important in it is to become aware of which of these phenomena and natural processes are provoked (and to what extent) by people. Knowledge of the causes of the changes would allow to specify the area of responsibility evaluated in the context of precautionary logic and preventive measures.

**Factors which accompany migrations**

It sometimes happens that a question appears in discussions on migration whether decisions to migrate are forced or voluntary, whether a migrant can assess (also from an economic point of view) and choose arguments which are more convincing or whether he sets out due to external pressure. It is true that economic factors are not too important in the third world countries, because it is not a question of what is more profitable – these people usually lose everything. This does not mean that the survival-related argument is unimportant - after all, it is about the most fundamental thing: will a change in the present place of living allow one to save one's life and health or not.

Disasters and changes in the environment caused by climatic alterations, which cause mass migrations, are usually accompanied by complicated political situations and armed conflicts. These processes and phenomena often coincide, which makes it impossible to distinguish one type of migration from another. For certain *convenience*, discussion of climate-induced and environmental migrants is combined with the general discourse on migrations and that the environmental/climatic factor is connected in an inseparable manner with the other reasons which affect migration decisions which are more or less forced (or more or less voluntary).

Therefore, who are those people who leave their homes due to factors to which they themselves have sometimes contributed? Why do they decide to do this; can they do anything to change the conditions in which they have to live? Do others who observe the climate changes, and correlated ecological effects, draw their own conclusions and are these conclusions constructive? Therefore, do they serve the purpose of alleviating the devastating effects which hurt both man and the environment?

It is estimated that the world is *hiding* about two hundred million people who have experienced the destructive effect of climatic factors. This applies mainly to developing countries. In consequence, these misfortunes usually affect the poorest, who have forever struggled against adversities which force people to focus on the issues at hand rather than on the future, which requires planning and long-term preventive and/or precautionary measures. What is possible are only (economically available) temporary corrective measures.

Each analysis of the issue reveals that temporarily delayed, but always accompanying effects of climate changes and natural disasters, effects include the destruction of fertile layers of soil, shortage of water

and the need to cut down forests for crop cultivation. As a rule, it is sufficient to upset the dynamic balance developed jointly by small rural communities, which usually live on the environment around them. Their safety depends on the ecosystem's ability to supply essential resources and on a range of social and institutional factors which describe how individuals, communities and whole societies can react to sudden and prolonged changes in the environment.

A change of place is a natural reaction to difficult situations. However, not everyone can do it. Some have to stay. Implementation of a decision requires economic resources and physical ability to reach another place. Elderly people and children usually cannot do it for natural reasons; women's capabilities are also restricted for cultural reasons.

**Who is a climate-induced refugee?**

So, who is a climate-induced/environmental refugee? The answer is not easy. It results largely from the lack of a widely accepted definition. One can see that the wider and less precise a definition, the more difficult it is to verify. Therefore, it applies to a larger number of people who could be assigned such a status. It is frequently accepted that this includes only people who were temporarily or permanently forced to leave their homes, households, workshops because of serious environmental damage which threatened their existence and/or deterioration of their living conditions. These include: a) people displaced temporarily due to local changes in the environment; b) people who migrate because environmental changes have restricted their means of support or deprived these people of them, pushing them to the border of acceptable risk; c) people who settle down in another place due to advanced desertification or other environmental changes usually caused by limited access to water in their environment.

Some people regard climate-induced and environmental refugees from a broader perspective, and also include in this category people who leave their homes as a result of the destructive effects of nature, but also of resource depletion, pollution, industrial disasters or armed conflicts. Attempts have also been made to determine the level of overall environment destruction to the extent which forces the people who live there to leave their homes as victims of (more or less violent and not only natural) phenomena and processes which leave their mark on the environment.

It is climate changes and migrations that have made the history of continents, adapted ecosystems and – indirectly – changed borders and united or dispersed nations. They have harmonised with evolutionary processes. They favoured selection, specialisation and then developing and diminishing of genetic and social polymorphism. It was, first unconsciously and then consciously, a progressive strategy which started before agriculture was invented and still continues. These migrations provided an alternative to moments of crisis, a way to survive, to save offspring as well as the material and cultural heritage of past generations.

Therefore, global climate changes have affected the history of mankind. Displacement of individuals and whole groups has always been associated with different reasons, contexts, effects, impact of human groups and climate, especially when it became absolutely necessary to leave a place where life was comfortable. Shortage of means has frequently been associated with wars and unrest. It is therefore obvious that climate-induced/environmental refugees, or refugees in general, are not a modern invention.

Nowadays, all those forced to flee for political reasons can/should be officially recognised as refugees and be protected by relevant conventions and international law (Mizerski, 2016). It is therefore logical that climate-induced refugees should also be provided with appropriate protection, even if - for obvious reasons - they cannot gain status equal to political refugees. Different options are possible[1], but no concrete legal solutions have yet been developed, either on a local or international level. Apart from legal and international solutions, it is obviously necessary to define areas and places with the greatest risks of adverse changes. They have their temporal characteristics and geographic location, for example, lowlands face the risk of a water level rise and excess of water, while others will suffer from its shortage. With relevant data, one could identify risky places for human settlements, cultivated land and concentration of industry and be better able to forecast losses in the economy and biodiversity, plan dislocations and take appropriate preventive measures and safeguard investments. This could be the basis for estimating the number of people who – when the time comes – will set out to search for a better place to live. For humanitarian reasons, one must develop scenarios which provide for at least minimal aid, which, however, may not be easy since it does not always take into account the specific nature of people from other spheres of civilisation. So the problem is a complex one; it includes religious, cultural, institutional issues, but also those related to data accumulation and processing. Therefore, efforts should be made to take decisions which – as far as possible – take into account the framework of rights and liberties – before any irreversible, consensual or forced actions are taken.

[1] Plans have been put forward to establish special funds and policies/initiatives for sustainable development. Maybe it would be better to develop long-term plans, action guidelines or to conclude inter-regional agreements binding neighbouring states with sufficient resources (following the example of Tuvalu and New Guinea), or more significant regions (e.g. between Europe and Africa).

## Size of the issue

Natural environment deterioration and natural disasters produce inestimable crowds of people forced to leave their homes. There clearly are more of such refugees than those fleeing from war and persecution (IFRC MEDIA, 2016). In some cases, it can be predicted who will be thinking of leaving their home in the near future.

Those concerned – mainly from the island states of Africa, the Caribbean, the Indian Ocean, the Pacific and the South China Sea[2] – are seeking new ways of solving their gravest problem. This subject was taken up by the Global Humanitarian Forum, which set itself the task of raising awareness of the growing danger and of providing support to those most threatened and those who are already experiencing effects of reckless actions of man. The report, devoted solely to the consequences of unsustainable actions of previous generations (and the current one) which have resulted in rapid changes in the environment, should make one ponder: 30 thousand victims and 325 million people severely affected by changes in the environment, which until now provided the living conditions at least at the minimum level. The same report says that 20 countries most affected by anomalies are responsible only for 1% of the emissions. On the other hand, over 90% of deaths and property destruction caused by climate changes happen in developing countries. What is more, forecasts of the dynamism of changes to 2030 are not optimistic.

It is true that many of them return to their homes after the destructive effect disappears, when the living conditions improve. But others prefer to look for a more friendly place within their own country or outside it. Forecasts are always imprecise, but it is supposed that there may be as many as 250 million climate-induced migrants in 2050.

However, the issue itself is much more complicated because there are too many reasons why people decide to emigrate. What is more, they can overlap and/or come in succession. Climate-related factors always *accompany* economic factors, and vice-versa. Four of them are the most important: two are progressive, they happen gradually, regularly, and two concern extreme, violent phenomena, which only sometimes happen more than once.

The first factor is the loss of land caused by rising level of the sea. Flooding of land and soil salinisation results in depriving people of the possibility of cultivating land, growing crops and conducting economic activities.

Another factor are prolonged droughts and desertification, usually in Africa and south-eastern Asia, in parts of Australia and New Zealand and in southern Europe. Combined with exploitation of natural and agriculturally-used ecosystems in excess of their actual capacity, they upset their balance and disrupt the process of providing goods and services.

The third factor are natural disasters, whose frequency, intensity and area are increasing from year-to-year, even where they were unknown previously.

The fourth and last factor are conflicts caused by depletion and limited access to natural resources (Czasak, 2013). Inevitably, this leads to serious tension and violence. Restrictions result from difficult access to, and the quality and amount of those resources, which always breeds misunderstandings, especially when one considers existing racial, race, language and other divisions.

## Outlook for the future

Considering the above, when one wants to take any precautionary measures (and even more so when these are to be corrective or aid measures) it becomes of key importance to recognise the existence of climate-induced/environmental migrants and to recognise them as an entity within national and international laws. Barring this, all specific initiatives undertaken will only be ad-hoc in nature, arising from social and individual sensitivity to another person's suffering and, to some extent, perhaps from a feeling of partial responsibility for the changes whose consequences are felt by everyone (though not by everyone equally).

The issue is extremely difficult and complex as climate-induced/environmental migrations have overlapped with – especially controversial from Europe's point of view – the arrival of refugees caused by the armed conflict in the Middle East. The influx of those fleeing from the cruelty of war has amplified the number of previous immigrants, including economic immigrants. Therefore, it should come as no surprise that Europe has started to perceive the immigration process as a public safety issue, striving to narrow down the area of recognised rights and to define consequences in relations between the concerned states.

It must be pointed out that most serious environmental and climatic problems are a consequence of irresponsible internal policies. A question arises about the responsibility of the governments of countries affected by the issue of *environmental collapse* caused by unsustainable management of natural resources, faulty (and sometimes maybe unfair) distribution of resources, maximisation of productivity of agricultural land beyond reasonable limits and destruction of accompanying natural ecosystems. State institutions are often indifferent to their own citizens drowning in poverty because of environment de-

[2] These countries which make up the Alliance of Small Island States (AOSIS) are intensifying their international activity in the areas that are important to them, i.e. preventing the effects of climate changes.

struction and alteration of conditions which do not allow one to survive (Janikowski, 2009). Therefore, climate-induced/environmental refugees are also becoming – to an extent – a political issue. However, for some reasons, they cannot be treated as equally as other migrants (political or economic). There is a principal difference between consequences of neglect of issues related to the environment and nature. However, one must be aware that adverse climate is, and will be, a factor which forces people to migrate to places which are more friendly and which offer better safety; in this case, these are, as a rule, countries of the rich northern hemisphere (Doronzo). Therefore, the international politics and interest of the scientific world should focus on exploring and raising awareness that future migrations to industrial countries will not be caused only by *traditional* factors, i.e. armed conflicts and poverty.

Climate changes are increasingly often connected as causes proportionally responsible for the tragic fates of millions of people. They are included in discussions on effective orientation of migration-related policies in accordance with the principles of humanitarian law towards those forced to move and according to the socio-economic and cultural capabilities of the communities which inhabit the target places. Better control and management of migration movements, based on the relevant regulations of international law, which take into account its special nature and complexity, would facilitate effective intervention of governments and competent organisations *at source*, in places affected by the effects. Recognition by institutions and permanent determination of the status of a climate-induced/environmental refugee would help to raise public awareness of essential issues of the natural environment, all the more so that the global dimension of the migration phenomenon is a sufficient reason for the need to make this effort, both on the local and global scale. However, no initiatives – political or economic – will bring a tangible change without people getting involved in economic activities which do not violate the principal natural basis.

**References**

(A) *Convention on the status of refugees* of 28.07.1951. (Journal of Laws, 1991 r. no. 119, item 515).
(B) Protocol on the status of refugees of 31.01.1967 (Journal of Laws, 1991 r. no. 119, item 517).
(C) Global Commission on International Migration (IOM), *Report Intergovernmental Panel on Climate Change* (IPCC).

1. CZASAK M., 2013, *Woda i jej zasoby jako czynnik potencjalnych konfliktów w XXI wieku*, in: P. Maciaszczyk, L. Kaliszczak (eds), *Wyzwania XXI wieku a człowiek i wiedza*, Tarnobrzeg, p. 73-82.
2. DORONZO S., *L'emigrazione ambientale: un fenomeno in continuo aumento*, http://www.isavemyplanet.org/altri%20temi%20ambientali/Doronzo-rifugiati%20ambientali%20in%20ok..pdf. (1.09.2016).
3. IFRC-MEDIA, 2016, *World disasters report 2015*, http://ifrc-media.org/interactive/world-disaster s-report-2015/ (1.09.2016).
4. JANIKOWSKI R., 2009, Development in Postmodern Time, IN: *Problemy Ekorozwoju/ Problems of Sustainable Development*, vol. 4, No 1, P. 131-134.
5. KOŚMICKI E., D. PIEŃKOWSKI, 2013, *In Search of the Present Economy and Society Modernisation Concept* (An Attempt to Explain the Main Problems), in: *Problemy Ekorozwoju/ Problems of Sustainable Development*, vol. 8, no 1, p. 115-123.
6. MIZERSKI, R., 2016, Gwarancje proceduralne na wypadek wydalenia cudzoziemca w systemie Europejskiej konwencji praw człowieka, in: *Studia Prawa Publicznego*, nr 3 (15), p. 61-97.
7. SITEK M., 2016, Kryzys uchodźczy a kryzys instytucjonalny Unii Europejskiej, in: *Journal of Modern Science*, vol. 28, no 1, p. 457-471.

**PROBLEMY EKOROZWOJU – PROBLEMS OF SUSTAINABLE DEVELOPMENT**
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# General Social Survey and Sustainable Development. Methodological and Empirical Aspects

# General Social Survey i rozwój zrównoważony. Aspekty metodologiczne i empiryczne

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## Abstract

Many large national research projects lack variables that would make it possible to monitor environmental attitudes on a regular basis. The General Social Survey (GSS), an American research program, can serve as an example of a good solution in this regard. The GSS surveys have used several variables at intervals of just a few years to measure environmental attitudes across time. The main aim of this article is to analyse these variables and show how they can be employed in other studies. Secondly, the article aims at presenting attitudes towards environment protection in contemporary American society on the basis of the 2014 GSS data. Variables describing the individuals' position in the social structure, such as income and occupational prestige score, turn out to have no influence on their environmental attitudes. By contrast, education and most of all age, are the most important characteristics that affect how strongly respondents feel about the need to protect the natural environment.

**Key words:** natural environment, attitudes, General Social Survey, indicator

## Streszczenie

W wielu dużych ogólnokrajowych projektach badawczych brakuje zmiennych, dzięki którym można byłoby w sposób ciągły monitorować postawy wobec ochrony środowiska naturalnego. Przykładem dobrego rozwiązania w tym zakresie jest amerykański program badawczy General Social Survey, w którym od lat, w sposób ciągły i w odstępach zaledwie kilkuletnich wykorzystuje się w badaniach kilka zmiennych mierzących tego typu postawy. Jednym z głównych celów artykułu jest analiza tych zmiennych i pokazanie perspektyw ich wykorzystania w innych badaniach. Drugim celem jest ukazanie postaw wobec ochrony środowiska naturalnego we współczesnym społeczeństwie amerykańskim, na podstawie danych GSS z 2014 roku. Zmienne opisujące położenie jednostek w strukturze społecznej, takie jak np. dochody i prestiż zawodu nie mają wpływu na tego rodzaju postaw. Wykształcenie, a przede wszystkim wiek – to najważniejsze cechy mające wpływ na siłę przekonań o potrzebie ochrony środowiska naturalnego.

**Słowa kluczowe:** środowisko naturalne, postawy, General Social Survey, wskaźnik

## Introduction

It is commonly known that the social component is one of the three pillars of sustainable development. Among various aspects that it encompasses, social attitudes towards environment protection seem to be one of the most important. This issue has long been present in social sciences research, with many empirical studies carried out within individual countries, but also of an international and comparative character. There exist, however, only few research projects that make it possible to monitor attitudes towards the environment in the long term and that make use of the same research methodology, thus allowing to reliably track trends in this important area across time. It is particularly important that such

long-term research should make use of the same measurement tools and should be carried out on relatively large research samples that are selected in the same way.

One of the research projects that meets these criteria is the International Social Survey Program (ISSP). It is a long-term international research program carried out annually in participating countries, and aimed at regular measurement of variables covering a broad scope of social life. The ISSP surveys are repeated every few years, which enables the observation of changes in the measured phenomena. One of the ISSP modules is the ISSP Environment, which was implemented three times – in 1993, 2000, and in 2010. The ISSP questionnaire surveys are carried out on random samples, and make use of both interview techniques and survey techniques.

Due to the range of topics it covers and its geographical scope, the ISSP Environment seems to be the most valuable research project in this field. However, its most serious shortcoming is that successive surveys are conducted at too long intervals (every 10 years and in the future this is not likely to change), whereas in order to monitor environmental attitudes more accurately, it is necessary to measure them every 2 or 3 years. So what are we left with in this situation? The answer could lie in large national research programs that meet the requirements described above and are conducted at shorter intervals. The American research program General Social Survey (GSS) is a good case in point here.

The GSS gathers data on contemporary American society in order to monitor and explain trends in attitudes, behaviours and attributes. The program has been conducted since 1972. The GSS contains a standard core of demographic and behavioural questions, as well as topics of special importance for the functioning of modern society. Among the topics covered are: civil liberties, crime and violence, tolerance, morality, national spending priorities, social mobility, and many others. The GSS is one of the best sources of data on the attitudes and trends in the United States. It allows researchers to examine the structure and functioning of society as a whole, as well as the role played by subgroups and to compare the United States with other nations. Its aim is to provide easy access to high quality data that can be used by researchers, students, policy makers, and others.

The experience of the GSS serves other large research program; for example, the ALLBUS (Die Allgemeine Bevölkerungsumfrage der Sozialwissenschaften), which has been conducted since 1980 to examine trends and consequences of social changes in Germany, or the PGSS (Polish General Social Survey) conducted since 1992. Both the ALLBUS and PGSS are based on the GSS, but unfortunately neither of them contains a single variable that could serve as an index (indicator) to examine environmental attitudes. Thus, a great opportunity for systematic monitoring of environmental attitudes in Central Europe has been missed, and there are no apparent prospects that the situation will improve in this respect. So, let us go back to the source that we have at our disposal, i.e. the GSS.

The aims of the article are twofold: methodological and empirical. In order to achieve the former ones, it is necessary to answer the following questions: What indicators of environmental attitudes does the GSS offer?; What are the properties of these indicators and to what extent are they suitable for systematic monitoring of environmental attitudes?. On the other hand, for the empirical aims to be fulfilled, it is necessary to answer the question: What has Americans' attitude to environment protection been in recent years and what does it depend on?

## Indicators of attitudes towards the environment

The 2014 GSS offers 3 variables that can serve as indicators of social attitudes towards environmental protection: NATENVIR used since 1973 (except for 2010), NATENRGY used since 2010, and WRLDGOV used in 1996, 2004, and in 2014.

The NATENVIR and NATENRGY variables are measured by the following survey question: We are faced with many problems in this country, none of which can be solved easily or inexpensively. I'm going to name some of these problems, and for each one I'd like you to tell me whether you think we're spending too much money on it, too little money, or about the right amount. Are we spending too much, too little, or about the right amount on (1) Improving and protecting the environment? (2) Developing alternative energy sources?[1] On the other hand, the WRLDGOV variable is measured by the question: Now we would like to ask a few questions about relations between America and other countries. How much do you agree or disagree with the following statement: For certain problems, like environmental pollution, international bodies should have the right to enforce solutions?

The GSS also contains the INTENVIR variable (used since 2008), measured by the question: Are you very interested, moderately interested, or not at all interested in issues about environmental pollution? This variable, however, does not seem to be suitable as an indicator of attitudes towards the environment, because it is very general and examines

[1] The 2014 GSS survey includes also the NATENVIY variable (which serves to assess attitudes to how much is spent on the environment), but this variable is not available in one sub-sample in which NATENVIR is used. As an indicator, NATENVIY can be used as an alternative to NATENVIR – it is up to the researcher to decide. In my opinion, NATENVIR is a better choice, as it is more specific and more understandable to the respondent. In addition, NATENVIR has been used longer (since 1973, while NATENVIY only since 1984), a fact that is important for long-term analyses.

only the respondent's declaration about the level of interest in environmental pollution. So it does not even measure the level of knowledge (the cognitive component of attitudes).

The number of variables related to attitudes towards the environment, as well as other variables connected with this issue varied in the past, depending on the year of a survey.[2]

Let us take a closer look at 3 indicators that seem to be the most promising in the GSS. The NATENVIR variable is unquestionably the most interesting one. It has been consistently used almost since the program started (except for the *environment* year 2010, when it was replaced with a set of questions from the ISSP). Secondly, it refers to the most important component of attitude (i.e. the affective and cognitive component), which is additionally expressed in economic terms, thus concerning all citizens. Spending money on protecting and improving the natural environment is not something abstract, a mere declaration of intent, but it has a very practical dimension associated with taking action. Considering its content, the variable is broad (protection and improvement of the environment); not only does it measure attitudes towards protecting the environment from degradation, but also towards restoring what has been degraded and may be restored. Therefore, the NATENVIR variable is simple, easy to understand, and it refers to relatively well-defined issues that can be translated into practice. The fact that is has been present in the GSS surveys for so long, is a good guarantee that it will be used in studies of this kind in the future, as well. Even if it is just one variable, its consistent use allows for regular measurements of attitudes towards environmental protection, which is extremely important for research into the social component of sustainable development. It is to be regretted that other nationwide programs (for example, the ALLBUS or PGSS, mentioned earlier) in which hundreds of different variables are employed, lack at least one that would refer to environmental attitudes.

The NATENRGY variable is much more detailed and it refers to investing in alternative energy sources to protect natural resources. Present in the GSS surveys only since 2010, it has been used in all studies since then. Consequently, it can be assumed that it constitutes a new and stable research proposal.

Another variable, WRLDGOV, describes a hypothetical situation. The respondent should express an opinion on whether for certain problems, like environmental pollution, international bodies should have the right to enforce solutions. It seems that when formulating this question, the researchers wanted to see to what extent Americans are ready (together with citizens of other countries) to give up some of their sovereignty concerning important environmental issues (such as pollution) in favour of international institutions. This variable is also more detailed than NATENVIR and has more political overtones. However, it has been used only occasionally and it seems that it was designed for surveys conducted at approx. 10-year-intervals. This makes it useful in a given survey year and for measuring long-term cycles, but it does not meet the requirement for variables needed for regular and frequent monitoring.

To conclude, the GSS contains 2 important variables that are well suited for frequent monitoring of attitudes towards environmental protection. These are: NATENVIR, which is well-established and more general, and NATENRGY, a relatively new and more detailed variable.

## Attitudes towards the natural environment

The 2014 GSS research sample consists of over 2,000 observations. However, since the GSS program carries out surveys on subgroups, not all questions are asked to all selected respondents. Consequently, the subset of respondents who were asked questions relating to environmental variables was smaller and included 1,123 people. Considering the large population of the US, it is a small sample but it was obtained with advanced selection methodology that has been improved over the decades.[3]

The sample included 47.6% of men and 52.4% of women (table 1). 75.7% of the respondents were white, 14.5% black and 9.5% had a different skin colour (table 2). The average age of respondents was 49 years (table 3).

Table 1. Sample structure by sex

| | Frequency | Percent |
|---|---|---|
| Male | 534 | 47.6 |
| Female | 589 | 52.4 |
| Total | 1123 | 100.0 |

As regards the variables describing social status, the respondents' average length of education was 14 years, their average occupational prestige score amounted to 48.5 points (on a scale from 0 to 90), while the monthly income typically ranged between $3000 and $3500 (table 3).

[2] For those interested in details, I recommend visiting the project website at http://gss.norc.org, and especially https://gssdataexplorer.norc.org/variables/vfilter, where after typing the word *environment*, you can find detailed documents showing how the *environmental* variables have been used in the GSS research in different years. It should be noted that many of these variables were used in the years 1993, 2000 and 2010, i.e. when the ISSP Environment module was conducted, and so in fact they belong to a different research project, which – as has already been mentioned – is not implemented frequently enough.

[3] Details on sample selection and other elements of the GSS methodology are available at http://gss.norc.org in: Get Documentation section (Appendix A and Appendix Q).

Table 2. Sample structure by race

| | Frequency | Percent |
|---|---|---|
| White | 850 | 75.7 |
| Black | 166 | 14.8 |
| Other | 107 | 9.5 |
| Total | 1123 | 100.0 |

Table 3. Sample structure by age, education and occupational prestige score

| | N | Mean | Std. Deviation |
|---|---|---|---|
| Age | 1119 | 48.99 | 17.086 |
| Years of education | 1123 | 13.92 | 2.960 |
| Occupational prestige score | 1081 | 48.48 | 25.843 |

As mentioned earlier, one of the most important indicators of attitudes towards environmental protection was the answer to the question whether too little, too much, or about the right amount of money is spent on improving and protecting the environment in the US (table 4). The vast majority of Americans (60.6%) believe that too little is spent on the environment. Only 9.4% hold the opposite opinion (i.e. they believe that the expenditure on environment is too high). 30% of the US population consider the amount of money spent on the environment to be the right one. By way of comparison, the respondents' answers were distributed similarly in 2004 and 1994 (in 2004 it was 63.3%, 7% and 29.7%, respectively, and in 1994 – 60.8%, 30.4% and 8.7%). The high percentage (nearly 2/3rd) of people concerned about environmental issues, has continued over the last years.

Table 4. Spending money on improving and protecting environment

| | Frequency | Percent |
|---|---|---|
| Too little | 680 | 60.6 |
| About right | 337 | 30.0 |
| Too much | 106 | 9.4 |
| Total | 1123 | 100.0 |

A very similar distribution of responses was obtained when another indicator was used – opinions about the amount of money spent on developing alternative energy sources (table 5). Also in this case, almost 60% (58.1%, to be precise) of Americans think that too little is spent on alternative energy sources in their country, while those who disagree with this opinion constitute only 10.8%. 31.2% are happy with the status quo. Making comparisons for this variable would not be very fruitful, because it has been present in the GSS surveys only since 2010 (as already mentioned).

Table 5. Spending money on developing energy sources

| | Frequency | Percent |
|---|---|---|
| Too little | 652 | 58.1 |
| About right | 350 | 31.2 |
| Too much | 121 | 10.8 |
| Total | 1123 | 100.0 |

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62% of Americans accept the interference of international institutions when important environmental issues are concerned, while 18.4% disapprove of it.
19.6% of Americans are undecided or have ambivalent feelings (*neither agree nor disagree*). To compare with the first two indicators, a similar high level of acceptance amounting to approx. 60%, is observed. By contrast, there are almost twice as many people (18.4%) who express the opposite opinion. A comparison of the 2014 data with the data from 1996 and from 2004 (when this variable was used in the GSS surveys) shows that the number of respondents accepting the interference of international bodies in the country's domestic affairs when the environment is concerned, has been gradually decreasing, whereas the number of those disapproving of such interference has grown (in 1996, it was 72.7% and 11.4% respectively, and in 2004 – 62.2% and 16.8%, respectively).

Table 6. International bodies should enforce environment solutions

| | Frequency | Percent |
|---|---|---|
| Agree | 696 | 62.0 |
| Neither agree nor disagree | 220 | 19.6 |
| Disagree | 207 | 18.4 |
| Total | 1123 | 100.0 |

To sum up, it can be stated that the 3 different variables illustrate a similar situation: nearly two thirds of Americans express opinions that can be interpreted as pro-ecological attitudes. This is basically a lasting tendency that has not changed over the last 20 years, apart from the opinion on interference of international bodies to enforce environment solutions.
The indicators considered are correlated (table 7). This correlation is stronger between the opinions on spending on environmental protection and on developing alternative energy sources (0.353). On the other hand, the opinions on spending on environmental protection and on enforcing environment solutions by international bodies, as well as those on spending on developing alternative energy sources and on enforcing environment solutions by international bodies are less correlated (0.254 and 0.190, respectively).
Determining the factors that influence the strength of pro-ecological attitudes is still another issue. In order to examine the socio-demographic determinants of such attitudes measured by the 3 indicators described above, regression for categorical data was used (table 8). This is a version of multivariate regression where variables can be used at any measurement level. The choice of this regression type is connected with the fact that the main dependent variables are measured at ordinal level, making it impossible to

Table 7. Spearman's rho correlations between dependent variables

| | | Improving and protecting environment | Developing alternative energy sources | International bodies should enforce environment |
|---|---|---|---|---|
| Improving and protecting environment | Correlation | 1.000 | 0.353 | 0.254 |
| | Sig. | . | 0.000 | 0.000 |
| | N | 1123 | 1123 | 1123 |
| Developing alternative energy sources | Correlation | 0.353 | 1.000 | 0.190 |
| | Sig. | 0.000 | . | 0.000 |
| | N | 1123 | 1123 | 1123 |
| International bodies should enforce environment | Correlation | 0.254 | 0.190 | 1.000 |
| | Sig. | 0,000 | 0.000 | . |
| | N | 1123 | 1123 | 1123 |

Table 8. Regression for categorical data: model summary and ANOVA

| Multiple R | R Square | Adjusted R Square | Prediction Error | F | Sig. |
|---|---|---|---|---|---|
| 0.212 | 0.045 | 0.030 | 0.955 | 2.967 | 0.001 |

Table 9 Regression Coefficients

| | Standardized Coefficients | | df | F | Sig. |
|---|---|---|---|---|---|
| | Beta | Estimate of Std. Error | | | |
| Age | 0.107 | 0.042 | 1 | 6.444 | 0.011 |
| Sex | 0.046 | 0.032 | 1 | 2.093 | 0.148 |
| Race | 0.068 | 0.036 | 2 | 3.529 | 0.030 |
| Education | -0.122 | 0.073 | 5 | 2.799 | 0.016 |
| Occupational prestige score | 0.073 | 0.048 | 1 | 2.324 | 0.128 |
| Income | 0.065 | 0.044 | 1 | 2.177 | 0.141 |

use multiple linear regression (which requires quantitative measurement of all variables). The following independent variables were selected for the regression model: age, sex, race, education (measured in years), occupational prestige score, and income (annual income).

The pro-environmental attitude measured by the opinion on how much money is spent on environmental protection (NATENVIR) depends on the respondent's age, race, and education (table 9). It does not depend on sex, occupational prestige score, and income. In this model, the influence of independent variables (beta value) is as follows: education has the most influence on pro-environmental attitudes; it is followed by age, and then by race. Model adjustment (adjusted R-square) equals 0.030, so the independent variables taken together explain 3% of the variance of the dependent variable. It is not much, but still the model is significant (p = 0.001).

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With the regression analysis results, we can take a closer look at the impact of the independent variables, which were included in the regression model (statistically, they are significant). It turns out that pro-ecological attitudes decrease with age and increase with the level of education (table 10). This can be seen from beta coefficients, as well as from additional comparisons of means. The average age of Americans who believe that too little money is spent on protecting the environment is 47.9, while those who believe that just right amount of money is spent and those who claim that too much is spent on the environment are aged on average 52.6 and 56.7. When it comes to education, the average length of education (measured in years) of Americans who

Table 10. Improving and protecting environment by age and years of education

| | | Age | Years of education |
|---|---|---|---|
| Too little | Mean | 47.87 | 14.05 |
| | N | 1106 | 1114 |
| | Std. Deviation | 16.364 | 2.922 |
| About right | Mean | 52.60 | 13.40 |
| | N | 573 | 574 |
| | Std. Deviation | 17.719 | 3.143 |
| Too much | Mean | 55.66 | 13.60 |
| | N | 187 | 188 |
| | Std. Deviation | 14.980 | 3.124 |
| Total | Mean | 50.10 | 13.81 |
| | N | 1866 | 1876 |
| | Std. Deviation | 16.891 | 3.025 |

Table 11. Improving and protecting environment by race

| | | Race | | | Total |
|---|---|---|---|---|---|
| | | White | Black | Other | |
| Too little | N | 831 | 186 | 98 | 1115 |
| | % | 58.7% | 63.5% | 58.3% | 59.4% |
| About right | N | 426 | 96 | 52 | 574 |
| | % | 30.1% | 32.8% | 31.0% | 30.6% |
| Too much | N | 159 | 11 | 18 | 188 |
| | % | 11.2% | 3.8% | 10.7% | 10.0% |
| Total | N | 1416 | 293 | 168 | 1877 |
| | % | 100.0% | 100.0% | 100.0% | 100.0% |

Table 12. Regression for categorical data: model summary and ANOVA

| Multiple R | R Square | Adjusted R Square | Prediction Error | F | Sig. |
|---|---|---|---|---|---|
| 0.196 | 0.038 | 0.024 | 0.962 | 2.760 | 0.002 |

Table 13. Regression Coefficients

| | Standardized Coefficients | | df | F | Sig. |
|---|---|---|---|---|---|
| | Beta | Estimate of Std. Error | | | |
| Occupational prestige score | -0.018 | 0.051 | 1 | 0.118 | 0.732 |
| Age | 0.140 | 0.070 | 1 | 3.925 | 0.048 |
| Education | -0.117 | 0.074 | 4 | 2.477 | 0.043 |
| Sex | 0.041 | 0.032 | 1 | 1.565 | 0.211 |
| Race | 0.074 | 0.028 | 2 | 6.941 | 0.001 |
| Income | 0.098 | 0.053 | 1 | 3.394 | 0.066 |

think that too little is spent on the environment is 14 years, just the right amount – 13.4, and too much – 13.6.[4]

African Americans display stronger pro-environmental attitudes than representatives of other races, with 63.5% agreeing that too little money is spent on

[4] The differences are seemingly smaller in the case of education as compared with age, but it has to be remembered that the length of scale length varies, with the scale for age at least three times longer than that for education. It also has to be remembered that even a small difference in years of education may sometimes significantly influence education level.

Table. 14 Developing alternative energy sources by age and years of education

| | | Age | Years of education |
|---|---|---|---|
| Too little | Mean | 48.85 | 14.16 |
| | N | 1393 | 1401 |
| | Std. Deviation | 17.070 | 2.859 |
| About right | Mean | 48.50 | 13.16 |
| | N | 783 | 783 |
| | Std. Deviation | 17.716 | 3.152 |
| Too much | Mean | 51.98 | 13.33 |
| | N | 256 | 257 |
| | Std. Deviation | 17.273 | 3.270 |
| Total | Mean | 49.07 | 13.75 |
| | N | 2432 | 2441 |
| | Std. Deviation | 17.324 | 3.037 |

Table 15. Regression for categorical data: model summary and ANOVA

| Multiple R | R Square | Adjusted R Square | Prediction Error | F | Sig. |
|---|---|---|---|---|---|
| 0.275 | 0.076 | 0.061 | 0.924 | 5.158 | 0.000 |

Table 16. Regression Coefficients

| | Standardized Coefficients | | df | F | Sig. |
|---|---|---|---|---|---|
| | Beta | Estimate of Std. Error | | | |
| Occupational prestige score | 0.045 | 0.057 | 1 | 0.644 | 0.423 |
| Age | 0.079 | 0.040 | 1 | 3.956 | 0.047 |
| Education | 0.133 | 0.129 | 5 | 1.056 | 0.384 |
| Sex | 0.082 | 0.039 | 1 | 4.556 | 0.033 |
| Race | 0.074 | 0.028 | 2 | 6.941 | 0.001 |
| Income | 0.098 | 0.053 | 1 | 3.394 | 0.066 |

protecting the environment, as compared with approx. 58-59% of Americans of other races (table 11). Only 3.8% of blacks agree that too much is spent on environment protection, as compared with approx. 11% of those belonging to other races.

The pro-environmental attitude measured by the opinion about the amount of money spent on developing alternative energy sources (NATENERG) depends solely on age and education (table 14). As with the previous indicator, the strength of pro-ecological attitudes decreases with age and increases with the level of education.

A comparison of means allows to specify the dependencies revealed in the regression analysis (table 16). The average age of Americans who believe that too little or just right amount of money is spent on developing alternative energy sources is about 49 years, while the average age of those who believe that too much is spent on developing alternative energy sources is approx. 52 years. Similarly, when education is considered, there is a difference between those who think that too little is spent on developing alternative energy sources (about 14 years of education), and the remaining two groups, namely those convinced that just the right amount of money or too much is spent on alternative sources (about 13 years of education).

These determinants show a similar strength of impact. Adjustment of the regression model is 0.024, so the independent variables account for 2.4% of the variance of the dependent variable. This model is also significant ($p = 0.002$).

The correlation model of pro-environmental attitudes measured by the consent to enforcing environment solutions by international bodies (WRLDGOV) is built in a slightly different way. In this case, the strength of pro-environmental attitude depends on age, sex and race, but it is not dependent on education, occupational prestige and income. Age, sex and race have a similar impact. The model adjustment is 0.061, so it is higher than in the previous two models. The independent variables taken together account for 6.1% of the variance of the dependent variable. This model is also is significant ($p<0.0005$).

Analyses that complement the regression model show that men are more likely than women (63.7% vs. 60.4%) to support enforcement of environment solutions by international bodies, but they are even more likely to disapprove of it (21% compared with

15.8% of women). This is connected with the fact that women are more often undecided (23.7% as compared with 15.3% of men). Some interdependency emerges, but it is difficult to indicate its direction. In this case, it is necessary to refer to the beta coefficient in the regression analysis or to compare percentage differences. No matter which method is chosen, it turns out that women are overall more likely to show pro-environmental attitudes (table 17).

Table 17. Opinion that for certain problems, like environmental pollution, international bodies should have the right to enforce solutions by sex

| | | Sex | | Total |
|---|---|---|---|---|
| | | Male | Female | |
| Agree | N | 354 | 374 | 728 |
| | % | 63.7% | 60.4% | 62.0% |
| Neither agree nor disagree | N | 85 | 147 | 232 |
| | % | 15.3% | 23.7% | 19.7% |
| Disagree | N | 117 | 98 | 215 |
| | % | 21.0% | 15.8% | 18.3% |
| Total | N | 556 | 619 | 1175 |
| | % | 100.0% | 100.0% | 100.0% |

As mentioned above, the strength of pro-environmental attitudes measured by the *interference in environmental issues* indicator changes with age. A comparison of extreme opinions (*I agree* vs. *I disagree*) reveals a significant difference in age (approx. 48 years as compared with approx. 54 years), which indicates that in general, pro-ecological attitudes decrease with age (table 18).

Table 18. Opinion that for certain problems, like environmental pollution, international bodies should have the right to enforce solutions by age

| | Mean | N | Std. Deviation |
|---|---|---|---|
| Agree | 48.30 | 724 | 17.083 |
| Neither agree nor disagree | 47.55 | 232 | 17.800 |
| Disagree | 53.65 | 214 | 16.493 |
| Total | 49.13 | 1170 | 17.243 |

White Americans and African Americans are more likely to disapprove of interference in environmental issues (19.5% and 18.1%, respectively, table 19) than representatives of other races (8.8%). On the other hand, the latter more often agree that international bodies should have the right to enforce solutions, which can be regarded as an indicator of pro-environmental attitude (67.3% as compared with 60-62% of white and black Americans).

## Conclusions

Many large national research projects that carry out regular surveys (e.g. the ALLBUS in Germany, PGSS in Poland, BSA in Britain, or TARKI in Hungary) lack variables that would make it possible to systematically monitor attitudes towards environmental protection.[5] The American GSS, in which several *environmental* variables have been used for many years and new ones are still added, is an example of a good solution; an example that should be followed. After all, environmental attitudes are no less important than, for example, political ones, which feature prominently in the social research. The GSS employs only a few *environmental* variables, but their number satisfies the minimum requirement as long as the ISSP Environment module is continued and regularly implemented. This allows for a much more detailed overview of environmental issues, though unfortunately at long intervals (the ISSP research into other social aspects is conducted more frequently). The research plan involving detailed and precise measurements made every 10 years, as well as regular monitoring, even if limited to only a few variables, but carried out every 2-3 years, seems to be a *minimum plan*. However, in order to implement it, it is essential to introduce environmental variables into as many national projects as possible. For this purpose, it seems reasonable to use the solutions offered by the GSS[6], if only to allow for comparative studies.

Until the situation changes, we are forced to rely on the ISSP Environment (a great project, but too seldom implemented) as the main source of environmental data. Can the data gathered in the GSS to regularly monitor environmental attitudes be used outside of the US? Can the research results for America be generalized onto other countries? I believe that they can, but only to a certain extent and with a considerable margin of error. People's attitudes towards the environment may be similar in countries that belong to the same civilization circle as the United States, countries of similar economic development, and facing similar environmental problems. Additional detailed analyses would be necessary to specify such countries, and their outcome is by no means certain.

What empirical conclusions can be drawn from examining the most recent GSS data? The most interesting thing is that the main variables describing the position of individuals in the social structure have no significant influence on their attitudes toward environmental protection. Income and occupational pres-

[5] These national programs cooperate with the ISSP and individual ISSP modules, including the ISSP Environment, are carried out within them. They lack, however, constant environmental variables that the GSS offers.

[6] For example, the ALLBUS and the PGSS have been modelled on the GSS since they were first implemented. It is to be regretted, though, that they lack the environmental aspect (several PGSS surveys conducted in the early 90s used the NATVIR variable, but then it was abandoned together with a whole set of similar questions).

Table 19. Opinion that for certain problems, like environmental pollution, international bodies should have the right to enforce solutions by race

| | | Race | | | Total |
|---|---|---|---|---|---|
| | | White | Black | Other | |
| Agree | N | 549 | 103 | 76 | 728 |
| | % | 61.6% | 60.2% | 67.3% | 62.0% |
| Neither agree nor disagree | N | 168 | 37 | 27 | 232 |
| | % | 18.9% | 21.6% | 23.9% | 19.7% |
| Disagree | N | 174 | 31 | 10 | 215 |
| | % | 19.5% | 18.1% | 8.8% | 18.3% |
| Total | N | 891 | 171 | 113 | 1175 |
| | % | 100.0% | 100.0% | 100.0% | 100.0% |

tige do not affect any of the three analysed indicators. The most important variables that influence how strongly respondents feel about the need to protect the environment are education, and especially age. Pro-environmental attitudes are most often observed among young and well-educated people.
What has to be remembered, however, is that the research sample was relatively small (compared to the total US population), which may lead to a considerable margin of error, despite advanced sampling methods that were used.

**References**

1. FRANKFORD-NACHMIAS CH., LEON-GUERRO A., 2014, *Social statistics for a diverse society*, Sage, London.
2. LAND K. C., MICHALOS A. C., SIRGY, J. (Eds.), 2012, *Handbook of Social Indicators and Quality of Life Research*, Springer, Dordrecht.
3. MARODY M., 1976, *Sens teoretyczny a sens empiryczny pojęcia postawy: analiza metodologiczna zasad doboru wskaźników w badaniach nad postawami*, PWN, Warszawa.
4. NOWAK S., 2016, *Metodologia badań społecznych,* PWN, Warsaw.
5. RYDZEWSKI P., 2010, Methodology and Key Issues of ISSP Environment Research Project from Sustainable Development Perspective, in: *Problemy Ekorozwoju/ Problems of Sustainable Development*, vol. 5, no 2, p. 51-60.

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# Tackling Sustainability from a Systemic Perspective: A Contextualized Approach

# Rozwój zrównoważony z perspektywy systemowej: podejście kontekstowe

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## Abstract
Sustainable development represents a shared aspiration, the priority of which is widely recognised worldwide by scientists, decision-makers and public opinion alike. It became a topic for reflection and an endeavour for initiatives taken by local communities, businesses, regions, states and international organisations. The subject of sustainability is interdisciplinary and involves a complex thinking that recently led to the emergence of a new discipline, namely sustainability science.
The systems approach (systemics) is deemed to offer a set of concepts and methods that enable the elaboration of visions, as well as the steering of the process of sustainable development in real contexts. Within this framework, the main strength of this approach consists in its capacity to overcome the reductionism peculiar to conventional perspectives on sustainability as being limited to greening and environmentalism.
The alternative perspective proposed by systemics is based on taking stock of the knowledge pertaining to the complex interdependencies between nature, society (including the economy), technology and the built environment. In short, systemics offers a background that is both pertinent and pragmatic and which enables the understanding of complex problems and the design of their solutions. One peculiarity of this approach resides in its capacity to foster the coining of new, meaning-rich concepts, usable in further theoretical and practical undertakings. Examples of such concepts include systemography, complexification, syntegrity, and co-opetition. This paper proposes a new such concept, that is sitesynthesis, rooted in the spirit of a given place and time.

**Key words:** sustainable development, systems approach, systemics, sitesynthesis

## Streszczenie
Rozwój zrównoważony jest wyrazem wspólnych aspiracji wyrażanych na całym świecie przez naukowców, polityków i opinię publiczną. To nie tylko temat do dyskusji, ale także do podejmowania konretnych inicjatyw i to na różnych poziomach: lokalnych społeczności, przedsiębiorstw, regionów, krajów i organizacji międzynarodowych. Zagadnienie zrównoważoności jest interdyscyplinarne i zakłada holistyczne podejście, które niedawno doprowadziło do powstania nowej dyscypliny naukowej, którą jest nauka dla zrównoważonego rozwoju.
Uznaje się, że podejście systemowe (teoria systemów) oferuje zbiór pojęć i metod właściwych dla wypracowania koncepcji, a także wdrażania rozwoju zrównoważonego w rzeczywistości. Główną zaletą tego podejścia jest przezwyciężenie redukcjonizmu, który jest cechą charakterystyczną tradycyjnego traktowania zrównoważoności, zawężonego do ekologii i środowiska.

Alternatywa, którą niesie ze sobą podejście systemowe, oparta jest na zasobach wiedzy odnoszącej się do złożonych współzależności występujących w świecie przyrody, społeczeństwie (w tym ekonomii), technologii i środowisku architektonicznym. Ujmując inaczej, podejście systemowe to podstawa, która jest trafna teoretycznie, a zarazem praktyczna, a która umożliwia zrozumienie złożonych problemów i przedstawia możliwe sposoby ich rozwiązania. Cechą szczególną tego podejścia jest zdolność do kreowania nowych szeroko zakrojonych koncepcji, które będą możliwe do wykorzystania w przyszłych tak teoretycznych, jak i praktycznych przedsięwzięciach. Wśród przykładowych koncepcji wskażmy na systemografię, syntensegrację i konkuperację. W niniejszym artykule zaproponowano kolejną taką koncepcję – to synteza zakorzeniona w duchu danego miejsca i czasu.

**Słowa kluczowe:** rozwój zrównowazony, podejście systemowe, teoria systemów, synteza miejsca

## 1. Introduction

Sustainable development is a subject which runs high in today's global agenda in scientific research and political decision-making. The public opinion in developed countries, as well as in developing ones, is showing an increased interest in this issue, and, in turn, the dynamics of the public discourse addressing it contributes to the further enhancement of this interest. The stake of sustainable development is highly relevant to the future of humanity due to its strong impact on life and the welfare of each citizen; thus, it involves a trans-generational perspective. These reasons led to placing this topic under the aegis of the United Nations, with a view to elaborating visions and achieving consensus on the initiatives of state and non-state actors. Agenda 21, designed under its auspices, set out the main landmarks regarding future actions of member states, as well as the cooperation amongst them, aimed at achieving sustainability. During the *Decade of Education for Sustainable Development*, proclaimed by the UN for the period 2005-2014, efforts were intensified for shaping visions for time horizons that allow for strategic engagement. In this respect, on 20-22 June 2012, the Rio 20+ Conference took place, 20 years after the Earth Conference held on June, 1992, in Rio de Janeiro. Both events having had a summit format and had gathered many high-level political decision-makers from all over the world. On these occasions, the concern was expressed with respect to the more diverse and tougher challenges, as well as the commitment to responding through focused, concerted efforts towards promoting sustainability. In 2012, the *Kyoto Protocol* which addressed the issue of limiting the greenhouse gas emissions into the atmosphere expired. Efforts to mitigate and countervail global warming were re-launched, in December 2015, at the Climate Conference (COP21) through the adoption of the *Paris Agreement*, concluded among 195 States that came into force on 5 October 2016.

In 2015, *the 2030 Agenda for Sustainable Development* (United Nations, 2015) was adopted. It established a set of 17 items titled *Sustainable Development Goals*. Within this context, the articulation between the sustainable development agenda and that of the information society turned out to be justified. In this respect, in 2015, the WSIS-SDG matrix (ITU, 2015) was elaborated; it mapped the sustainable development goals onto the action lines for advancing the information society and was adopted at the High-level Meeting WSIS+10, held in Geneva on 10-13 June 2014 (ITU, 2014).

Currently, preparations are underway for the next High-level Political Forum on Sustainable Development to be held in New York on 10-19 July 2017. The Forum is expected to gather representatives from all the member states of the UN and its specialised agencies.

The events and official documents mentioned above are widely known and frequently referred to in government circles and the media; the reason to thereby cite them is to draw some contextualised insights. From the succession and subjects of the respective events, one can note that awareness is already present worldwide, at top decision-making level, about the currency of the issue of sustainable development and the need to pursue its goals in the long run. Two key imperatives with respect to the manner of tackling the respective issue can be discerned: vision and consensus building at international scale, as the problem at hand is global in scope, with stakes and implications alike. Top-down approaches, although necessary, are not sufficient. It took longer to raise awareness and to trigger involvement for promoting sustainability locally but, once activated, these factors started to play a role that tends nowadays to take precedence in terms of concrete outcomes. Two new kinds of stakeholders became more active in recent years: local communities and businesses. The sustainable development objective is particularly fit to the call of thinking globally and acting locally. Businesses are engaged in promoting sustainable development goals mainly by exerting their own corporate social responsibility in ways that protect customers, employees, local communities and the environment at large. It is worth mentioning that, in 2010, the World Business Council for Sustainable Development crafted a vision (Infosys, 2010) the time horizon of which spans to 2050, while governments' foresight horizon is until 2030.

The bottom-up approach got stronger in the 2000s. By contrast to top-down ones which express general concerns and set goals and action lines in rather broad terms, local initiatives are owing their vigour to the fact that they are directly addressing concrete

needs and have engaged stakeholders; thus these initiatives reap either praise or criticism from their beneficiaries. An example in this respect is the industrial symbiosis of Kalundborg (Jacobsen, 2006), a Danish harbour, where local businesses joined local governing bodies and the community in successfully designing and implementing, on a collaborative basis, a circular system of recycling water, steam and waste, while preserving the environment, safeguarding local working and living conditions and saving energy and other resources.

The remaining of this article includes a contextualised review of the foundations of systemics, as well as a practical example, aimed at arguing that promoting sustainable development involves a systemic approach in thinking and in action. Such an approach is useful for conceptualisation and foresight purposes, as well as for steering on-the-ground, actions aimed at achieving sustainable development within specific frameworks of space, time and agency.

Conceptualisation and foresight, regarding sustainable development require a systemic approach mainly due to the interdisciplinary character of the body of knowledge that pertain to it. These knowledge pieces originate from various disciplines, belonging to diverse science fields (life/natural sciences, regional, socio-economic and technical/engineering ones); therefore, a systemic referential becomes necessary that would allow for articulating such a composite knowledge base. For example, tackling systemically the theme of the global climate change, that is emblematic for the current spectrum of sustainable development, involves integrating knowledge originating not only from climatology, but also from geography, biology, physics and even medical and social sciences (Stehr and von Storch, 2009, p. 35).

On the other hand, in actual terms, the specific problems raised by achieving sustainable development are encountered within large-scale, dynamic systems. Their management involves monitoring and prediction over a wide range of parameters and also coordinated interventions over numerous factors of causation and influence, their outcome having an intricate, propagated impact. The essential vocation of the systems approach is to be anti-reductionist. The conventional way of addressing sustainable development is, most frequently, still focused on greening. Such a focus is over-simplifying, as it eludes the complexity of the phenomenon and the compensatory intervention needed. Therefore, the argument is hereby adopted that a comprehensive optic, of the kind of *sustainability beyond greening* is required (Dragomirescu and Marinescu, 2012). The issue of sustainable development is structured in terms of the relationship between the natural environment, the man-made environment (including the technological, the built and even the virtual ones) and society. After all, sustainable development is more about society and nature considered together, rather than just nature. The former involves not only protecting nature as habitat, but, more significantly, protecting the essence of humanity itself. In the same line of thought, one can also mention the proposal to widen the scope of the sustainable development concept *so as to include ethical, technical/technological, legal and political aspects* (Pawłowski, 2008).

This paper lays down an annotated review of the main characteristics and strengths of the systemic approach, as compared to the conventional, analytical approach; the latter has still a considerable bearing on contemporary science. It puts forward a new concept, namely s*itesynthesis*, which is introduced with respect to an example of a proposed re-design of a residential settlement in Malta.

## 2 The systems approach: an annotated review of key tenets

According to Senge (1990, p. 7), *systems thinking is a conceptual framework, a body of knowledge and tools that has been developed over the past fifty years, to make the full patterns clearer, and to help us see how to change them effectively.*

This characterisation is particularly useful because it is pointing out that systemics has a two-fold bearing: onto thinking and onto acting. At the thinking layer, taking a systemic stance means ensuring accurate representations of reality and enabling design changes consisting of either creating new systems or transforming existing ones. At the action layer, systemics offers grounds for intelligently enacting, steering and undertaking interventions upon or within systems. As such, systemics is applicable to any active entity from nature, artefacts pertaining to infrastructure/technology, economy, society or human intellect.

Systemics reached its maturity in the mid 1980s, mainly based upon the developments occurred in social, cognitive and information sciences. Among its prominent promoters are Edgar Morin and Jean Louis le Moigne, pioneers of the new paradigm of complexity. The school of thought founded by them is centred on the study of complexity (see e.g. Morin, 2011; Le Moigne, 2013). Morin (1993) defines the system as *the global and organised totality of the relationships that tie together certain entities, actions or individuals.* Complexity is understood not as a feature intrinsic to the system, but peculiar to every observer's perception on the system (Le Moigne, 2013) and thus complexification is recommendable (Eriksson, 1997), by contrast to the traditional simplification (Le Moigne, 1990, p. 165), usually symbolised by Occam's razor. Examples of other notable schools of thought in the field of systemics are Santa Fé Institute (www.santafe.edu) and New England Institute for Complex Systems (NECSI, necsi.edu), both based in the USA.

Contemporary systemics built upon contributions that emerged in mid 20th century, some key ones belonging to Norbert Wiener, who coined the fundamental concept of feed-back, and Ludwig von Bertalanffy (François, 1999). The latter created an unified, general systems theory, according to which all systems, irrespective of their content and context of existence, are exhibiting a set of common properties. This meant a major leap as compared to the pre-systemics thinking, within which specific systems (e.g. biological, technical, social, astronomical etc.) were studied separately by the respective scientific disciplines

As, in systemics, the key logical operator is conjunction, a canonical form of the general system was proposed as a juncture of two conjunctions (Le Moigne, 1990, p. 38): the synchronic, between the system and its environment, and the diachronic, between the functioning of the system and the transformation that occurs by default as the former operates. The implications that can be further derived are highly significant and mark a shift from previous conventional wisdom. According to Le Moigne (1990, p. 40), the first conjunction entails that every system is meant, either explicitly or implicitly, to pursue a certain goal. The system is identifiable by the respective goal, and not, as previously considered, by its content, borders, label etc. Thus, systemic thinking has a projective, goal-centred orientation, and this feature has major implications for practical applications. Conventional wisdom used to imply that, since the system is hosted within its environment, the former is somehow captive inside, always enduring the influence of the former, without exerting, in turn, any significant influence over it. By contrast, systemics conveys the rather counter-intuitive hint that, while being subject to external influences, the system is also influencing its own environment, and can even induce its transformations.

Also according to Le Moigne (1990, p. 40), the diachronic conjunction of the canonical form is emphasising the aspect of becoming, the transformation that occurs along the path of the functioning of the system, that affects its constitutive parts, the internal and external relationship of the respective system. This diachronic conjunction of the canonical form of the general system is particularly useful for understanding the limits of the overuse of socio-economic modelling that attempt to derive the future exclusively from the past.

Mainstream economics is facing nowadays heavy criticism as being unable to anticipate accurately future states and trends. There is still a propensity to pursue, in nowadays socio-economic research, an effort of excessively sophisticating the mathematical models, to use more and more refined quantitative techniques. Yet, trends identified in the past and transposed into mathematical functions stand only if one assumes continuity, meaning that the same path/correlation valid in the past is applicable to future prediction purposes. Although the use of such functions is popular in today's socio-economic research, one should be aware of the relativity of the results thus obtained. We live now in a time of turbulence, where changes are mostly unpredictable, disruptive, and with high propagated impact, thus the assumption of omnipresent continuity is questionable.

Besides its goal centeredness and the focus placed upon interactions and dynamics, the systems approach has the merit of privileging the synoptic way of encompassing realities under scrutiny, as opposed to the *dissection* type of approach proposed by the Cartesian tradition of knowing by analysis.

One of the educational implications of the adoption of the systems approach is the possibility of adding generalist's abilities to the specialist's ones. The generalist is no longer defined as someone who knows something about everything; he/she is a specialist who can communicate and collaborate with other peers from different fields, on the unifying platform offered by systemics. This aspect has a key relevance for sustainability as an endeavour involving multi-disciplinary knowledge base and collaborative action among specialists and teams from different disciplines and cultures.

The strengths of systemics are rendering it particularly fit to applicative undertakings aimed at ensuring sustainable development: risk evaluation and mitigation, cross-impact studies, complex project management, articulating public policies in a coherent mix, design of new systems etc. In sum, many of these kinds of interventions would thus be of the kind of systemic changes that provide a viable alternative to the obsolete type of reparatory ones that can only patch, but not effectively and sustainably solve problems.

Systemics allows highlighting the shortcomings of the mechanistic approaches imported by social sciences from the technical ones. A mechanism is certainly a system, but not any system should be reduced to a mechanism. Mechanicism still present in economics is challenged by the systems approach on the grounds of the reductionism of the former. In terms of systemics, reductionism is generally understood as an attempt to represent a system through considering its parts separately (see e.g. Bar-Yam, 2011), while giving less or even no consideration to the interactions among these parts, thus actually risking to misrepresent or even elude the whole.

For instance, the mechanistic logic of the balance is still widespread in mainstream economics in the study of equilibrium. The clause *cæteris paribus* is, in turn, also reductionist, as it eludes the simultaneity of the dynamics of different parts of the systems. This clause also distorts the understanding of causation in socio-economic systems, because it tends to associate the whole variation of the output only to

the single parameter considered variable; all other parameters are conventionally considered as fixed, which factually is not the case.

**Systemics is also pointing out to the obsolescence of the prejudice of linear causality (Le Moigne, 2007) and thus replaces it by circular causality. Accordingly, cause and effect are not permanent statuses of certain entities; they could switch to one another over time, while loops are key patterns in the phenomenology of dynamics and interaction. This aspect is also of particular relevance for sustainability, which involves recycling and, in general, the application of the principles of circular economy.**

The contrast between the analytical approach, through which the positivist paradigm is operationalised, and the systems approach, as the core of the emergent paradigm of complexity, is presented in Table 1 with respect to a range of key features.

Table 1. Comparison between analytic and systemic approaches, based on De Rosnay (1975, p. 108)

| Analytic approach | Systemic approach |
|---|---|
| Knowledge is meant to allow for the derivation of theories and models of generally valid truthfulness | Knowledge is meant to allow for the derivation of intelligible representations of reality that are pertinent to certain projects of intervention upon that reality |
| Knower is purpose-neutral and independent from the object of inquiry | Knower is purpose-oriented and interacts with the object of inquiry |
| Focus on elements; disjunction is the key logical operator (separating, isolating) | Focus on interactions between elements; conjunction is the key logical operator (associating, articulating) |
| Rigorous, detailed models (e.g., econometric models) | Models of a limited rigor, still useful for decision-making and action (e.g., Models of the Club of Rome) |
| Leads to knowledge accumulation into specialized disciplines | Leads to multi- and inter-disciplinary integration of knowledge |

Taking into consideration the arguments based upon the strengths of the systemic approach, as evidenced by the comparison presented in Table 1, one can assume that the alternative paradigm could offer the epistemological grounds for the emerging science of sustainability.

## Proposing the systemic concept of sitesynthesis and illustrating its practical applicability

This section introduces and discusses, within an applicative context, the concept of sitesynthesis which derives from taking a systemic stance in tackling a practical issue. It is illustrated by the design of an architectural and urban redevelopment project referring to a specific locality in Malta. The intellectual motivation for crystallising this concept stemmed from the need for understanding the manifold and evolving context of a site in its totality, by integrating its natural/environmental, socio-economic realities, along with the wellbeing aspirations of the inhabitants and the public perception. By proposing this concept and embedding it into a specific local development project, instead of being a conventional architectural exercise, the respective proposal took the form of a systemic redesign of a human settlement geared to be sustainable. Integrating sustainability dimensions into the architectural design is a rather recent orientation, given that, in the 20$^{th}$ century, most notably with Modernism and the related International Style, the end product of residential architecture was in line with the dictum of Le Corbusier, *the house is a machine for living in* (1986, p. 4). From the systemic perspective, the quoted dictum and the practices based upon it exhibit clear marks of reductionism. Although traditional approaches in architecture take into account the physical characteristics of the site itself, they are doing so by considering these aspects separately rather than as a nexus. The concept of sitesynthesis offers the possibility of zooming on the items/aspects of the built environment, as well as the process of building design and erection, in a comprehensive manner, within the wider context that integrates also the human and natural dimensions into a synoptic representation.

In order to illustrate the conceptual fitness and the practical applicability of sitesynthesis, we will outline some considerations relating to a design proposal for the re-development of a settlement in Malta. By taking a systemic stance, the proposal was conceived, in architectural terms, in order to ensure the progress on the respective settlement on the path of urbanisation, whilst also rendering it more compliant to the sustainable development objective at local level.

The preparation of the re-development proposal took place over the period July-September 2009. It was undertaken by an inter-disciplinary team of professionals, ranging from architects and environmental consultants to an expert in statistics, at Lino Bianco & Associates. The concept of sitesynthesis emerged in the research work that grounded the design of the re-development proposal.

The settlement subjected to re-development is the caravan and bungalow site at Għadira, in mainland Malta, legally established in the late 1970s when Prime Minister Dom Mintoff was in office. The site, located off Mellieħa Bay, supports 236 residential units, hence forming a settlement equivalent to a full-scale village. The area surrounding the site is characterized by a coastal alluvial wide valley bed, the northern sector being on a slope with heavy terracing, whilst the southern is an unterraced plain.

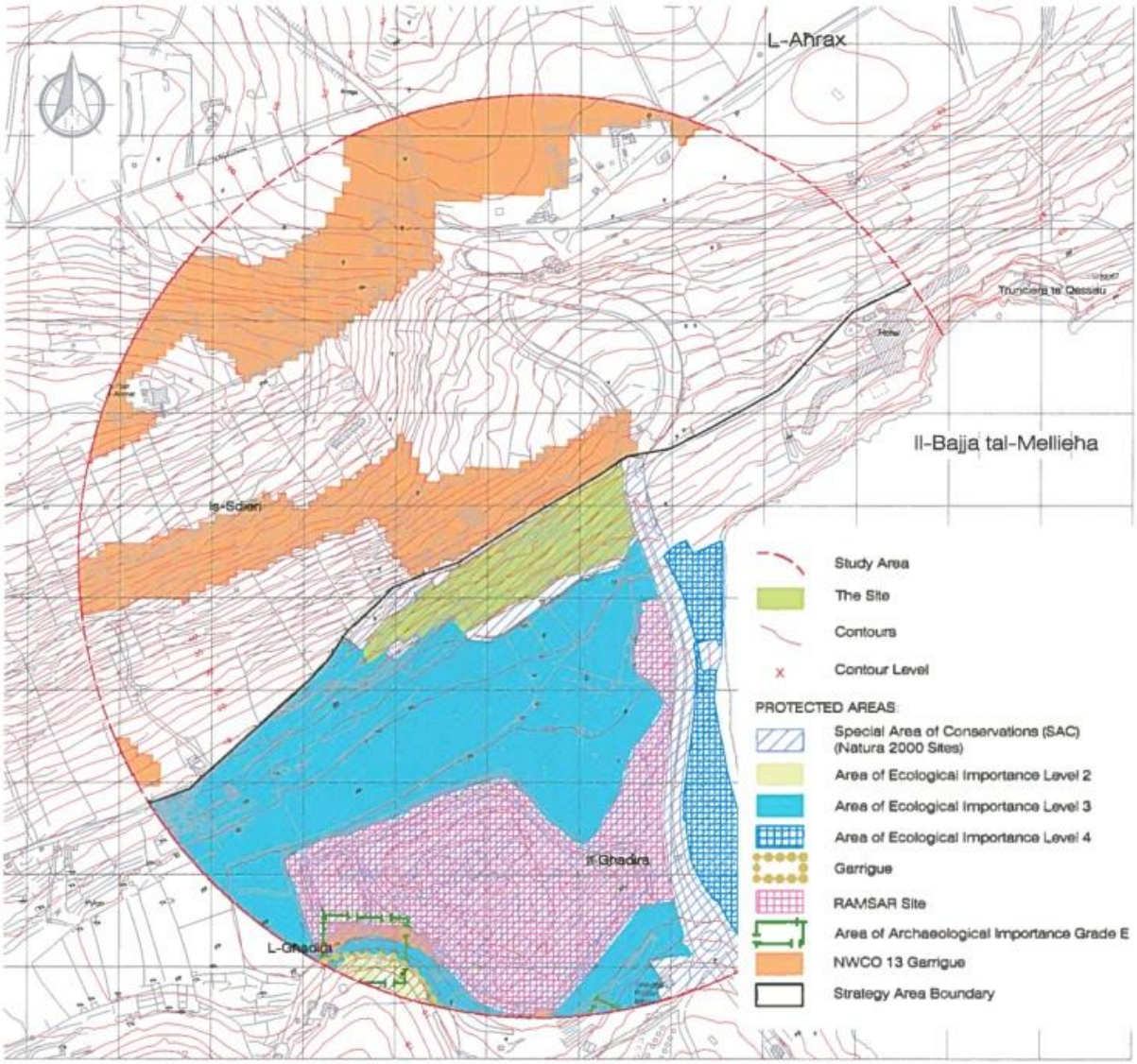


Figure 1. Areas graded for their natural heritage importance, source: Lino Bianco & Associates

The locale is a catchment area to the largest sandy beach in the Maltese Islands. With a Foresta 2000 site to the north and a Natura 2000 site to the south, the respective area is eco-sensitive and has considerable visual impact on the surrounding landscape. A description of the concerned area which covered a diameter of 1km around the site, based on fieldwork covering land uses and natural heritage, has already been published (Bianco, 2016); the sites which are graded and protected by law are plotted in Figures 1 and 2.

The Association of Caravan and Bungalow Owners, known in Maltese language as Assoċjazzjoni tas-Sidien tal-Caravans u Bungalows, was set up in 1978 to manage the site, organise activities for the community and bring forward issues related to the site to the attention of the public agencies concerned (Assoċjazzjoni tas-Sidien tal-Caravans u Bungalows, 1981).

Having a surface area of 316 km$^2$, Malta is the largest island of the Maltese archipelago, a group of islands located 96km south of Sicily and 39 0km north of Africa. Its climate is typically Mediterranean, characterised by hot dry summers and mild, wet winters. The island of Malta is rich in architectural and urban history and supports impressive cultural built heritage complexes, some labelled as World Heritage sites listed by UNESCO (1980). Besides significant geo-cultural landscapes, Malta sustains picturesque, terraced natural landscapes with occasionally endemic flora and fauna (Schembri and Sultana, 1989). Applying the I-distance method to the sustainable development indicators of the *EU Sustainable Development Strategy* (Eurostat, 2010), the I-distance value for Malta, which ranked in the 8$^{th}$ position of the 27 member states of the European Union at that time, is 18.726. Sweden ranked 1$^{st}$ with an I-distance value of 44.645, whilst Slovakia, at 3.838, was in the last position (Radojicic et al, 2012).

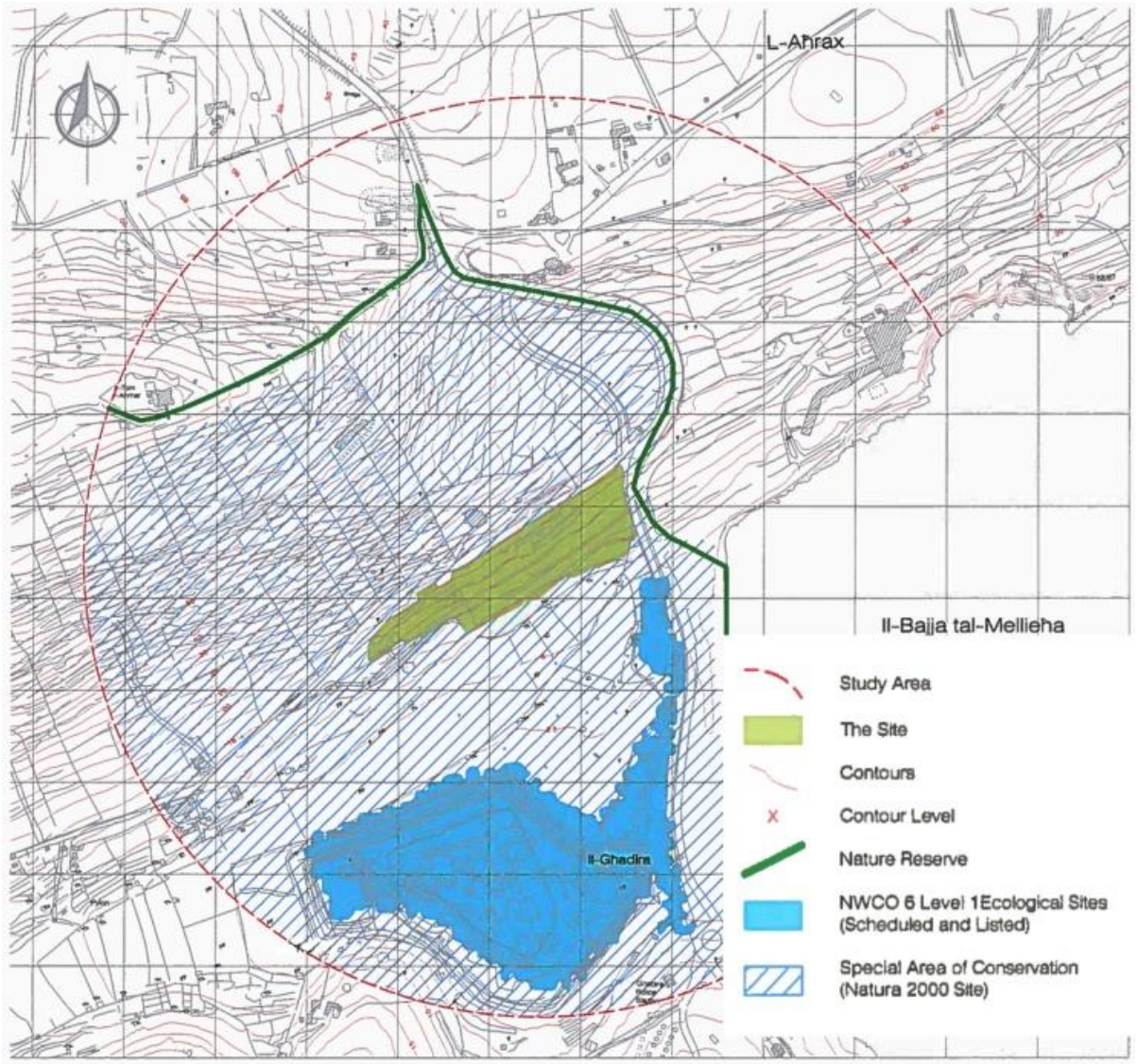


Figure 3. Protected areas for natural heritage significance, source: Lino Bianco & Associates

This method, proposed and elaborated by Ivanovic (1973), was the basis for the statistical approach developed by Radojicic et al. (2012) to measure sustainable development, through ranking countries in terms of their respective level of development, based on a number of indicators.

Along the years, from seasonal mobile units, caravans eventually became permanent on site. At present, most of them are constructed through cheap building materials, mostly recycled, rendering them intrusive with respect to the natural landscape, and also not appealing in appearance; others are erected in load-bearing masonry construction. The style of the caravan units is truly that of an *architecture without architects* (Rudofsky, 1964). They are mostly built by the caravan owners to suit their own individual needs, breaching local sanitary laws and regulations in force. The only obligation which was not actually breached is the external bright green colour of the unit, a condition imposed on the caravans by the Government (the colour was chosen by virtue of Press Release number 504 issued by the Department of Information, Castille, Valletta, in 1978). The site at Għadira is no exception (Assoċjazzjoni tas-Sidien tal-Caravans u Bungalows, 2008). As to the architecture of the caravans, a few ended up erected in more durable material and thus known as bungalows, developed through the actions of the builders, namely the occupiers of the site. By necessity, it is an expression of the socio-economic, cultural and technological realities adjusted to the physical characteristics of the site.

Given the negative reaction towards such caravan sites, rooted in the general public's consciousness of environmental planning and equally shared by environmental activists and NGOs, the Association of Caravan and Bungalow Owners decided, in 2009, to propose a re-design of the respective settlement. This initiative entailed the upgrading of a poor quality and intrusive caravans and bungalows to become an environmentally-sensitive settlement which respects both the physical characteristics of the site and the

needs of the residents. The scope of this assignment fell outside the remit of the Association; given the growing commitment of its members to induce improvements on the residential units, the architecture and environmental planning practice Lino Bianco & Associates was requested to develop a design solution with a view to improving the existing site.

The vision adopted for the redeveloping of the site aimed at integrating, in a systemic perspective, the environmental setting with the residents' requirements. In re-designing the site, it was considered essential to maintain a balance between the environmental backdrop, the community needs and the provision of essential public services, sustainability and security. Thus, the objectives of the proposed re-design, dictated by the environmental and social considerations, were the following:

1. Understanding the community's sense of its own existence, so that a more favourable perception by the general public emerges, mainly through refining the visual impact of the settlement, after implementing the re-development scheme.
2. Developing a social profile of the existing settlement through a census of the inhabitants and the respective typologies of units occupied by them, thus ensuring that the proposed design is backed by a wide positive social response.
3. Triggering a regenerative catalyst for the site through reaching upper standards for habitation for the existing community, whilst respecting the physical characteristics of the site and also meeting the expectations of the public opinion countrywide.
4. Developing locals' social responsibility, as a success condition of the implementation of the redevelopment of the existing settlement and
5. As the present settlement is the resultant of erections by the builders of the individual caravans/bungalows, there is no elite, be it the architect or the Committee of the Association of Caravans and Bungalows Owners, who will condition and/or dominate the layout of the re-designed settlement.

The urban planning layout was developed through participatory engagement with the residents (Bianco, 2016), this participation being itself a feature of sitesynthesis. Residents' engagement rendered the local development planning a constructive process for both the individual inhabitants and the community at large, thus the advancement towards urbanisation was facilitated. The application of sitesynthesis led to a blueprint that, when implemented in practice, would have a favourable impact in terms of sustainable local development. In principle, the authors share the view, that the actual chances to prevent the degradation of the environment and to promote sustainability are still low; but, presumably, this is due to the fact that too few projects yet are designed and implemented in a systemic optic. Sitesynthesis appears, in this context, as a counter-example; it is a conceptual and pragmatic architectural and urban design option that supports sustainability, at least at local level.

## Conclusions

The above considerations pertaining to the re-development proposal for the Għadira site should not be misread by lack of official implementation, as the formal initial assignment was limited only to the preparation of the scheme. The respective settlement is still in place and thus the preparation of its re-development proposal can be read as catalytic to a conceptual innovation and also as a social experiment. Two main outcomes can be noted:

1. There is a general-purpose research outcome consisting in the elaboration of the systemic concept of sitesynthesis that could be further extended to other applicative contexts, and
2. The preparation of the re-development proposal, even though lasting a few months, involved comprehensive surveys and fieldwork that led to comprehensive understanding of the local problems relevant not only to the issue at stake, but also to the broader agenda of sustainable local development.

Moreover, the social engagement with the respective project (Bianco, 2016) can be further interpreted as a demonstration for the feasibility and usefulness of the collaboration between professionals and local inhabitants in preparing a viable proposal for re-developing the respective settlement. Thus, the common platform of thinking and acting being already laid out, also benefitting from the use of systemic tools, the implementation of the proposal, at the time chosen by the authorities, will be facilitated.

## References

1. ASSOĊJAZZJONI TAS-SIDIEN TAL-CARAVANS U BUNGALOWS, 1981, *Statut*, Vexillina Press, Rabat, Malta.
2. ASSOĊJAZZJONI TAS-SIDIEN TAL-CARAVANS U BUNGALOWS, 2008, *Caravan Site Għadira: 30 Anniversarju 1978-2008*, Caxton Printshop Ltd, Mrieħel, Malta.
3. BIANCO L., 2016, Participatory engagement in urban design process: the case of an urban settlement in Malta, in: *Spatium*, vol. 35, p. 71-78.
4. BAR-YAM Y., 2011, Concepts: Reductionism, http://necsi.edu/guide/concepts/reductionism.html (09.05.2016).
5. DE ROSNAY J., *Le Macroscope. Vers une vision globale*, Seuil, Paris, 1975.
6. DRAGOMIRESCU H. and MARINESCU S., 2012, Sustainability Beyond Greening, in: *Green*

*Economy and Competitiveness*, eds. Magda S. and Dimya L., Károly Róbert Kft. Press, Gyöngyös, p. 1023 - 1029.
7. ERIKSSON D., 1997, A Principal Exposition of Jean-Louis Le Moigne's Systemic Theory, in: *Cybernetics and Human Knowing*, vol. 4, no 2-3, p. 35-77.
8. EUROSTAT, 2010, *EU Sustainable Development Strategy*, http://epp.eurostat.ec.europa.eu/portal/page/portal/sdi/indicators/
9. (05.10.2016).
10. FRANÇOIS C., 1999, Systemics and Cybernetics in a Historical Perspective, in: *Systems Research and Behavioral Science*, vol. 16, no 3, p. 203-219.
11. IVANOVIC B., 1973, *A method of establishing a list of development indicators*, United Nations Educational, Scientific and Cultural Organization, Paris.
12. INFOSYS, 2010, Vision 2015, *The new Agenda for* business, https://www.infosys.com/newsroom/features/Documents/2050-agenda-business.pdf (5.10.2016).
13. ITU, 2015, *WSIS – SDG Matrix. Linking WSIS Action Lines with Sustainable Development Goals*, https://www.itu.int/net4/wsis/sdg/Content/wsis-sdg_matrix_document.pdf (09.05.2016)
14. ITU, 2014, *WSIS + 10*, https://www.itu.int/net/wsis/implementation/2014/forum (5.10.2016).
15. JACOBSEN N. B., 2006, Industrial symbiosis in Kalundborg, Denmark. A quantitative assessment of economic and environmental aspects, in: *Journal of Industrial Ecology*, vol. 10, no 1-2, p. 219-255.
16. LE CORBUSIER, 1986, *Towards a New Architecture*, Dover Publications, Inc., New York.
17. LE MOIGNE J.-L., 1990, *La Modélisation des Systèmes Complexes*, Dunod, Paris.
18. LE MOIGNE, J.-L., 2013, The Intelligence of Complexity: Do the Ethical Aims of Research and Intervention in Education Not Lead Us to a New Discourse "On the Study Methods of our Time"?, in: *Complicity: An International Journal of Complexity and Education*, vol. 10, no 1-2, pp. 1-17.
19. MORIN E., 2001, The Epistemology of Complexity, in: *New Paradigms, Culture and Subjectivity*, eds. Fried Schnitman D. and Schnitman J., Hampton Press inc. Cresskill, NJ., p. 325 -340.
20. MORIN E., 1993, The Concept of System and the Paradigm of Complexity, in: *Context and Complexity: Cultivating Contextual Understanding*, ed. Maruyama M., Springer, Heidelberg, p. 125-138.
21. PAWŁOWSKI A., 2009, How many dimensions does sustainable development have?, in: *Sustainable Development*, vol. 16 no 2, p. 81-90.
22. RADOJICIC Z., ISLJAMOVIC S., PETROVIC N., JEREMIC V., 2012, A Novel Approach to Evaluating Sustainable Development, in: *Problemy Ekorozwoju/ Problems of Sustainable Development*, vol. 7, no 1, p. 81-85.
23. RUDOFSKY, B., 1964, *Architecture without Architects: A Short Introduction to Non-Pedigreed Architecture*, Doubleday & Company, New York.
24. STEHR N. and VON STORCH H., 2009, *Climate and Society, Climate as Resource, Climate as Risk*, World Scientific Publishing Company, Singapore.
25. SCHEMBRI P. J., SULTANA J. (eds),1989, *Red Data Book for the Maltese Islands*, Department of Information, Valletta.
26. UNESCO, 1980, *Megalithic Temples of Malta*, http://whc.unesco.org/en/list/132 (05.10.2016).
27. UNITED NATIONS, 2015, *Transforming Our World: the 2030 Agenda for Sustainable Development* (A/RES/70/1), https://sustainable development.un.org/content/documents/21252030%20Agenda%20for%20Sustainable%20Development%20web.pdf (09.05.2016).

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# Social Responsibility, Internal Governance and Manufacturing Growth

# Odpowiedzialność społeczna, zarządzanie wewnętrzne a wzrost produkcji

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## Abstract
This article presents a structural equation model for exploring the impact of social responsibility, which been divided into responsibility for the internal stakeholder and responsibility for the external stakeholder, as well as internal governance on Chinese manufacturing growth on the basis of data collected from 500 manufacturing enterprises in the East region of China. Our results show that both social responsibility and internal governance have a positive impact on manufacturing growth and promote sustainable development in manufacturing. In addition, social responsibility has a positive impact on internal governance, and the internal governance plays a partial intermediary role in the impact of social responsibility on manufacturing growth. These findings signify that it is important for Chinese Manufacturing to undertake Social Responsibility, and it can provide a beneficial guidance for Chinese Manufacturing Growth and help strengthen the competitive advantage of manufacturing industry.

**Key words:** social responsibility; internal governance; manufacturing growth; structural equation model

## Streszczenie
Artykuł przedstawia model równania strukturalnego odnoszący się do społecznej odpowiedzialności, wyróżniając w jej ramach odpowiedzialność za wewnętrznego oraz zewnętrznego akcjonariusza i wewnętrzne zarządzanie w kontekście wzrostu produkcji w Chinach, w oparciu o informacje uzyskane z 500 firm pochodzących ze wschodniej części kraju. Przeprowadzona analiza pokazuje, że zarówno społeczna odpowiedzialność, jak i wewnętrzne zarządzanie, mają pozytywny wpływ na wzrost produkcji i promocję zrównoważonego wytwarzania. Ponadto społeczna odpowiedzialność ma pozytywny wpływ na wewnętrzne zarządzanie, a w oddziaływaniu społecznej odpowiedzialności na wzrost produkcji, wewnętrzne zarządzane odgrywa po części rolę pośrednika. Uzyskane rezultaty wskazują, że społeczna odpowiedzialność jest ważna, może pełnić rolę dobrego doradcy w kontekście wzrostu chińskiej produkcji i pomóc w zwiększeniu konkurencyjnej przewagi dla przemysłu wytwórczego.

**Słowa kluczowe:** odpowiedzialność społeczna, zarządzanie wewnętrzne, wzrost produkcji, model równania strukturalnego

## 1. Introduction

As a strategic branch, advanced development of manufacturing industries is the prerequisite for most countries to achieve industrialization and is also the pillar of the country's economic development and enhances its strength comprehensively. This is especially important in China, where industrialization is still at the initial stage. Manufacturing is not only a major component of Chinese economy, which provides the main material basis for industrialization and modernization, but also a key factor to social and economic sustainable development (Zhang, 2013). Therefore, under the policy of constructing a harmonious society in China, guiding manufacturing attention to stakeholder's demands and consciously bearing social responsibility has become an urgent need for Chinese manufacturing, as well as for the Chinese society, in order to maintain a healthy and sustainable development.

The in-depth development of economic globalization and the continued adjustment of world industrial structure speed up the transfer of manufacturing from the developed countries to the developing countries. At the same time, the rapid development of high-growth industry, including iron and steel industry, automobile industry and equipment industry etc., will promote China to undertake this international industrial transfer action and thus become the world's manufacturing base. However, since the introduction of reforms and opening up, China's economic level has gradually narrowed the gap with the developed Western countries, which resulted in raising the living standards of people. Additionally, the characteristics denoting early development stage of Chinese labor, such as low wages and low welfare, do not exist anymore. Therefore, at the present stage, China's manufacturing is facing enormous challenges of change, including the continuing rise of raw materials and energy prices, introduction of various government regulations, the fading advantage of low-cost labor , which consist of conventional core competence (Ding, 2010), as well as the demand of creating a harmonious society and the enhancing the social responsibility awareness. All these factors forced Chinese manufacturing enterprises to make appropriate adjustments. Wang Ruixiang, the president of China Machinery Industry, claimed at Social Responsibility Forum of equipment manufacturing industry in 2013 that fulfilling the social responsibility is an important measure to enhance manufacturing competitiveness and a powerful guarantee for achieving sustainable development in manufacturing. He also proposed that if manufacturing industry could seize the China's transformation opportunity and fulfill the social responsibility conscientiously, it would be possible for them to overturn the traditional development model and ensure the improvement in the growth of quality.

The theory of corporate social responsibility comes from the article entitled *Businessmen's social responsibility* written by Bowen (1953), and it was introduced to China in 2001. In 2002, China Securities Regulatory Commission issued *Corporate Governance Guidelines* clearly requiring the listed companies to pay attention to corporate social responsibility. In 2006, new *Company Law* explicitly required that companies engaged in business activities must shoulder social responsibility; at the same year, Shenzhen Stock Exchange established *Shenzhen Stock Exchange listed company social responsibility guidelines* which advocated listing companies actively committed to social responsibility. In 2012, SAC (Supervision and Administration Commission) further suggested that all central corporate should issue a high quality social responsibility report. Public opinion, government regulation and corporate sustainable development, all these require enterprises not only should care about the shareholder wealth but should also pay attention to stakeholders' interests and fulfill social responsibility in a conscious manner. However, in practice, many scandals, such as *poison capsule event*, *Foxconn event* and so on, made public anxious about the socially responsible behavior related to manufacturing. What social responsibility should the manufacturing industries assume and what will be its impact on the long-term development performance of a company, have become important practical problems restricting the sustainable development of manufacturing. The existing research about manufacturing growth mostly concerns the matters related to the industry concentration, firm size, and profitability. Other topics including, for instance, what is the social responsibility of manufacturing and how does the social responsibility affect the growth of manufacturing, are rarely involved. On the basis of the above-mentioned analysis, this study investigates the manufacturing growth problem from the perspective of social responsibility, which has an important theoretical and practical significance and can provide useful guidance for manufacturing growth and thus strengthen the competitive advantage of manufacturing.

## 2. Research theories and hypothesis

### *2.1. Related theory*

#### *2.1.1. Manufacturing growth*

Manufacturing growth corresponds to the process experienced by manufacturing companies, from weak, small and immature to mature, powerful and competitive ones, occurring under the combined effects of dynamic mechanism in their life cycle. Manufacturing growth is reflected in two dimensions, i.e. *quantity promotion* and *quality promotion*. Quantity promotion refers to the increase in the output value and overall size expansion and so on; on the hand, quality promotion refers to technology maturity and organization rationalization (Zhou, 2000). Zhang

(2013) proposed that the overall development of manufacturing industry should include the following connotations: (1) improvement of competitiveness of enterprises; (2) increase of enterprise value; (3) rationalization of enterprise behavior and enterprise system.

Growth factors directly determine the path of manufacturing growth path and its efficiency. Hence, the related analysis is important for the scholars intending to explore how the manufacturing growth may be improved. Shah (2003) and Gungor (1999) believed that the frowth of manufacturing is mainly influenced by the external environment which consists of customers, shareholders, community and government regulations. Vachon (2008), Ward (2000) and Ilgin (2010) thought the heterogeneity and dynamic characteristics of manufacturing resources is the basic factor to promote the growth of manufacturing in a sustainable manner. Zhu (2003) suggested that the driving force behind the manufacturing growth comes from the improvement of core competitiveness which is brought by technological innovation and continuous changing. Yang (2010) believed that the factors governing manufacturing growth still constitute a black box, that is, the influencing factors are complicated, involving knowledge, evolution, innovation, legal and other aspects. On the basis of the influence factors, scholars constructed a variety of manufacturing growth index. Dunne (1992), Delmar (1997), and Merz (1995) thought that the volume of sales constitutes a parameter which is suitable for measuring the manufacturing growth. Pesaran (1995) & Kuroiwa (2010) considered the employment opportunity as the growth index conforming to the viewpoint of resource determinism in man agement theory, and it seems to be a reasonable choice. Cheng & Xing (2003) studied the relationship between growth, capital structure, and scale by using the main business income to express the growth of manufacturing. Their obtained results showed that there was a significant positive correlation between scale and growth. The statistics of specific construction index found in existing literature was shown in table 1.

Table 1. Indicators of manufacturing growth

| Authors | Indicators of manufacturing growth |
|---|---|
| Karnani (1982), Dunne (1992), Merz (1995), Delmar (1997) | sales volume |
| Penrose (1959), Kogut (1992) | employment opportunities |
| Enoch (1978), Fagerberg (1988), Menzler-Hokkanen (1989) | unit labor cost |
| Gustavsson and Lundberg (1999), Tinvall (2004) | enterprise scale, total output and trade openness |
| Cheng and Xin (2003) | the main business income |
| Wang and He (2005), Yao (2006) | main business growth rate, net profit growth rate |
| Sun (2006), Zeng (2007) | Tobin Q |
| Zhang (2002), Zhang (2003), Chen (2006) | market share, export growth rate |
| Lu (2002), Li and Han (2005) | sales growth rate, the proportion of output value accounted for GDP, profit rate |

As evident from the practice situation and study literature both Chinese manufacturing industry and scholars are concerned more about the financial dimension. The main business growth rate, net profit growth rate and total assets market value, have become the key factors to measure the manufacturing growth. In comparison, few scholars choose stakeholders and internal governance as the factors to measure manufacturing growth. On the basis of the above-mentioned analysis, this paper aims to make an appropriate amendment and to discuss the manufacturing growth from the dimension of social responsibility and internal governance.

*2.1.2. Social responsibility*

The improvement of material living standards, and the education level, as well as opening to the outside world, constitute the people's expectations towards the corporate social responsibility, thus setting the development trend of social responsibility for all enterprises in the world. As for the Chinese manufacturing industry, which is moving towards the international market, this trend is undoubtedly a new challenge. As early as 1953, Bowen proposed that corporate social responsibility is derived from society expectations towards an enterprise and the enterprise needs to develop policies, make decisions and take actions in accordance with the requirements of social goals and values. The social contract and values must be respected by the manufacturing industry, when they fulfill their own social role and deal with their relationship with the society. There are more than 100 different definitions in the existing research and some of them are controversial. With the increasing impact of corporate social responsibility and the increasing scope and intensity of public's attention, conducting in-depth studies and attempting to solve this problem has become a common aspiration of both academia and business community.

Carroll (1979) created a *four responsibilities* concept framework based on social responsibility object and claimed that corporate social responsibility includes economic, legal, ethical and voluntary responsibilities (the latter was subsequently changed to *charitable responsibility*). The *four responsibilities* conceptual framework reveals that enterprises cannot be solely responsible for the interests of shareholders, but should also assume responsibility for the interests of all defined stakeholders, including shareholders, managers, employees, consumers, suppliers,

government, natural environment, community, etc. This definition by Carroll is actually close to the concept of *corporate responsibility* proposed by Brammer (2007), and also consistent with the concept of *comprehensive social responsibility* claimed by Zhou (2005), as its aim is to emphasize the role and function of enterprise in the whole society. Clarkson (1995) defines the stakeholders of enterprise based on legitimacy, power and urgency first, and then advocates that an enterprise should be responsible for ensuring all stakeholders can share the enterprise's residual ownership and residual control rights. This proposition combines the corporate social responsibility and daily business activities in an appropriate manner, so that the corporate social responsibility can be implemented in specific practice.

Similarly, based on the stakeholder theory, Chang (2004a) carried out an in-depth analysis on the scope of enterprise's responsibility for internal stakeholders (employee). On the other hand, Ju et al. (2005) and Jin (2006) studied the responsibility of an enterprise for the external stakeholder (customer). You (2003) divided social responsibility into six dimensions, on the basis of the source of the pressure exerted on the manager in the consideration and implementation of the management decisions: responsibility to the public, to the investors, to the customer, to the government, to the competitors, and to the staff. He also put forward the main responsibility behavior of each dimension.

Specifically, employing the stakeholder theory to study corporate social responsibility has the following benefits: ① it defines the object of social responsibility; ② it defines the specific contents of social responsibility; ③ it defines the scope of social responsibility; ④ it provides scientific methods for measuring the social responsibility. Based on this theory, this article divided social responsibility of manufacturing into two dimensions from the perspective of stakeholders: social responsibility to the internal stakeholders the external stakeholders. The internal stakeholders mainly include shareholders, managers and employees, whereas the external stakeholders mainly include creditors, suppliers, distributors and consumers, as well as to the government, environment and community.

*2.1.3. Internal governance*

The concept of internal governance was proposed by Williamson (1975). He attributed *internal governance* to *system* category, claimed that internal governance mainly becomes effective in system environment. In the early 1980s, *internal governance* concept began to emerge in economic literature. Blair (1995) believed that internal governance is the relationship between stakeholders, as well as the institutional arrangements for formulating this relationship, and pointed out that the interests of creditors, customers, the board of directors, management and employees should be placed in the same position as the interests of shareholders. Qian (1995) defined the internal governance on the basis of the practice of developed market economy as: a whole set of institutional arrangements to deal with the relationship between different stakeholders (shareholders, lenders, management and staff, etc.), including: how to configure and exercise the control right; how to monitor and evaluate the board of directors, managers and employees; how to set up and implement an incentive mechanism, etc. Tirole (2001) points out that internal control is a system design, which can improve the welfare level of all stakeholders and, at the same time, restrain supervising the operator.

From the perspective of the internal governance evolution and the range of stakeholders involved, the concept of internal governance can be understood as a series of legal, institutional and cultural institution arrangements involved in the organization mode of enterprises, control mechanisms and the distribution of interests. It is not only related to operator's restraint, incentive mechanism design and institutional arrangement, but also to the arrangement of incentive and constraint system for all stakeholders. It does not only correspond to the governance problems related to shareholders, the board of directors, the board of supervisors and management, but also to the relationship among shareholders, creditors, suppliers, employees, government, community and other stakeholders. Xu (2009) believes that the internal governance can bring two advantages to an organization: ① Forecasting – the internal control can better internalize the shock cost brought by the external operation of an organization and also can quickly and timely make appropriate response to the relevant events based on the advantage provided by information. ② Direct change in the performance – the internal governance is a routine control program which, by supervising and adjusting the behavior of managers, can guarantee that operators will make an optimized operation. Therefore, it plays a leading role in improving the management efficiency of an organization. Xu (2009) even proposed that the ownership control mechanism, i.e. the board supervision mechanism and the operator incentive mechanism should be set as the measurement index for the internal governance of Chinese manufacturing industry.

*2.2. Hypothesis deduction*

*2.2.1. Social responsibility and manufacturing growth*

Jones (1995) believed that the reason why an enterprise should bear social responsibility and be concerned about stakeholders' interests is because the social responsibility will help the enterprise become more profitable. If the enterprise takes the risk to neglect the social responsibility and oppose the interests of stakeholders, it may endanger their own survival. In other words, an enterprise needs to take the social responsibility and consider the stakeholders' interests, because these can be used as a means and

tools to achieve the purpose of enterprise management. If assuming the social responsibility does not help an enterprise to improve their performance or even deteriorates it, no enterprise will assume the social responsibility anymore. Therefore, the practical significance of studying social responsibility is obvious: if the assumed social responsibility has positive impact on the enterprise performance, enterprises will actively take the social responsibility for their own interests as an entity pursuing profit maximization, and this is also what the society expects. If the impact is negative or there is no significant relationship between them, an enterprise will evade assuming social responsibility in order to avoid taking the risk. Thus, if we want enterprises to take the social responsibility, we should find other ways rather than rely on the enterprise's will or initiative. This problem has drawm the interest of many researchers for its important theoretical and practical value. Greenley & Foxall (1997) used the data from a questionnaire survey to examine the relationship between the social responsibility and the performance of an enterprise. Results show that the social responsibility and corporate performance are positively related in the case of controlling market growth, but this relationship depends on external environment and has been regulated by malicious competition. Waddock & Graves (1997A, 1997b) use the stakeholder relationship (SR) – representing the corporate social performance – and the perceived corporate management level (PMQ) representing corporate overall performance to research. Results show that the social performance of an enterprise and corporate overall performance have a very significant positive correlation. Li (2006a) takes 521 Listing Corporation in Shanghai stock exchange as a sample to study the relevance of enterprise social responsibility and enterprise value. He drew the following conclusions: in the short term, the greater the social responsibility behavior, the lower the value of enterprise; however, in the long term, the assumed social responsibility would not reduce the value of enterprise. Shen (2006) also studied the relationship between the social responsibility performance of an enterprise (CSP) and its financial performance (CFP). The results showed that they were positive correlated to a significant degree. Based on these analyzes, this paper puts forward the following hypothesis:

Hypothesis 1: undertaking social responsibility has a positive effect on manufacturing growth.

Most of the previous studies show that companies can set up high quality stakeholder relationships by taking social responsibility to meet stakeholders interests. These relationships can subsequently reduce risks, promote innovation, enhance reputation, expand market, increase opportunities, and establish competitive advantage (Wheeler & Svendsen, 2003). However, the social responsibility in previous studies has seldom been defined as the responsibility for the internal stakeholders and the responsibility for the external stakeholders. Actively assuming responsibility for external stakeholders is important in the modern market economy and is related to enterprise financing, government support and public recognition, etc. This can not only affect the reputation brand awareness, and even the soft power of an enterprise, but also its sustainable development. On the other hand, by meeting and balancing the requirements of the internal stakeholders, an enterprise can improve their ability to meet the external stakeholders' needs and improve the security of the enterprise growth performance. According to the previous definition on the operation of the social responsibility (Wood, 2003; Wu, 2006; Wheeler, 2003), if one enterprise assumes higher responsibility for the internal stakeholders and neglects the responsibility for the external stakeholders, whereas another enterprise neglects the responsibility for the internal stakeholders and commits higher responsibility for the external stakeholders, these two enterprises may have the same social responsibility performance. This is because all these studies believe that there is no difference between the responsibility for the external stakeholders and the responsibility for the internal stakeholders. This approach will not make understand people why enterprises take responsibility for different stakeholders. The impact on the growth of an enterprise is different, and may even mislead the direction of its social responsibility behavior towards the responsibility object. In this paper, we will discuss the influence of assuming the responsibility for the internal stakeholders and the responsibility for the internal stakeholders on manufacturing growth, respectively. Only in this way, we can truly understand the different influence of various types of social responsibility behavior on the enterprise growth. Therefore, this paper puts forward the following two sub-hypotheses:

Hypothesis 1-1: undertaking social responsibility for the internal stakeholders has a positive impact on manufacturing growth.

Hypothesis 1-2: undertaking social responsibility for the external stakeholders has a positive impact on the manufacturing growth.

*2.2.2. Social responsibility and internal governance*

Early theory research about the social responsibility of an enterprise mainly focuses on the concept and moral level. On the basis of the early research on the social responsibility concept, Ackerman (1973), Bauer (1976) and Frederic (1978) proposed three phases of enterprise social responsibility management process: Understanding social needs – Person in charge – Organization participation. This process turned the research on the social responsibility of an enterprise from the level of concept to the level of management. These authors believe that assuming social responsibility is not a burden to an enterprise, but rather it can be seen as a long-term investment behavior and will bring a competitive advantage and

return in future. Therefore, the internal governance system adapted to social responsibility should embody the following characteristics: ① It should encourage managers to consider the business behavior from the perspective of social responsibility and increase the weight of long-term incentives in managerial incentive model. ② The organization's mission, vision and organizational spirit, should be characterized by greater social responsibility. ③ The organization, its rules and regulations etc., cannot stay in line with the requirements of laws and regulations and meet the relevant interest groups only. Instead, they should be reformed in accordance with the requirements of the social responsibility. Only in this way, an enterprise can meet the development requirements of the social responsibility at this stage.

Social responsibility is a kind of enterprise resource reserves which can be transformed into its competitive advantage. Without it, an enterprise will fall into a passive condition and can even be eliminated when the market changes. However, the category and content of social responsibility are not fixed and they can be transformed into each other under certain conditions; therefore, the internal governance variables of an organization which are affected by them will be transformed as well. That is, the management objects and social responsibility level of an enterprise are different in different stages, and this difference is ultimately reflected in the internal governance of the organization, which is the internal cause of undertaking the social responsibility.

Hypothesis 2: undertaking the social responsibility has a positive effect on the internal governance.

Hypothesis 2-1: undertaking the responsibility for the internal stakeholders has a positive impact on the internal governance.

Hypothesis 2-2: undertaking the responsibility for the external stakeholders has a positive impact on the internal governance.

*2.2.3. Internal governance and manufacturing growth*

Principal-agent theory believes that the purpose of the internal governance is to monitor operators' behavior to protect owners' interests and promote long-term growth of enterprises. In the real economy, this process is realized through specific internal governance mechanism, which mainly includes ownership, board supervision and operator incentive mechanisms.

The ownership mechanism governance mainly concerns the governance of ownership concentration degree and ownership balance. Horinouchi & Hanasaki (2004) made an empirical analysis on Japanese enterprises from 1970 to 2000. Their results show that ownership concentration is positively correlated with the corporate performance. Xu (2006) took 4845 listed Chinese corporations as the research sample in order to make a linear regression analysis and shows that there is a significant positive correlation between the ownership concentration and the corporate performance. Nagar (2000) found that the performance of a company which has a number of major shareholders holding a similar proportion of shareholding or the first largest shareholder holding a higher proportion of shares, is better than other companies. Chen (2004) and Lin (2005) claimed that ownership balance mechanism has a positive effect on the corporate performance. Among the studies on the effect of board supervision mechanism on the manufacturing growth Holmstrom (1991) thinks that setting up a board supervision mechanism will produce a better incentive for the operator. However, most of remaining literature presents a more pessimistic conclusion that the board supervision mechanism has almost no effect on the performance of a company (Baysinger, 1985; Bhagat, 2002; Miyashima, 2004). Empirical research results and the original intention of establishment-independent director supervision mechanism are not the same. If the independent director system and the corporate performance are irrelevant, why did enterprises generally implement such a mechanism? This seems to be a contradiction and requires conducting a further in-depth study. In theoretical research about the influence of managers' incentive mechanism on the growth of enterprises, Song (2005) selected the listing corporation, which been listed before 2002 as the research sample. The results show that the operator holding and company performance are not or weakly related. However, the research based on listed manufacturing industries carried out by Litenberger (1994), Sasaki & Yonezawa (2000), Long Palk (2001), Gao & Song (2007) shows that the relation between operator holding and corporate performance is positive.

Since the beginning of a new century, large Multi-National enterprises have entered the Chinese manufacturing market through direct investment and expand a strong competition dependent on its absolute advantage of capital, technology and management. All these factors made the competition among domestic manufacturing enterprises become intense. The fierce competition stimulates the consciousness of enterprises, as they not only learn the limitations of advanced technology, but also reference and improve the advanced internal governance mode positively. Chen (2009) divided Taiwanese manufacturing industry into *high ability enterprises*, *medium capacity enterprises* and *low capacity enterprises* – three categories according to the internal learning and governance capacity. His empirical analysis was based on the structural equation model shows that the improvement of governance has a positive effect on the establishing a competitive advantage of an enterprise. On the basis of the practical situation and literature, this paper puts forward the following hypothesis:

Hypothesis 3: the internal governance has a positive effect on the manufacturing growth.

*2.2.4. Social responsibility, internal governance and manufacturing growth*

In the studies on how an enterprise takes social responsibility, scholars usually study it from the perspective of *enterprise behavior*. The widely accepted 3D model of *principle-process-result*, built by Wood (1991), is also increasingly often given with the meaning of enterprise behavior. The definition of corporate social responsibility principle has been transformed from the government and social level to the enterprise level and has become the specific guiding principle of dealing with the social responsibility. Effective corporate governance used internal control mechanism to inhibit stakeholders' opportunistic behavior, improve the stakeholder information symmetry, protect stakeholder's legitimate rights, and ultimately maximize the stakeholder interests as well as promote taking social responsibility by an enterprise in an effective manner (Denis, 2000). At the same time, in the process of internal governance, the value for stakeholders is created and the perfection of ownership mechanism, board supervision mechanism, operator incentive mechanism are all beneficial to reducing the uncertainty of management results, improving the completeness of contractual liability to stakeholders, reducing the post-supervision cost, ensuring the effective supply of exclusive right capital and related resources, and ultimately benefiting the value creation of stakeholders and the whole process of enterprise growth.

In conclusion, it is not difficult to see that the social responsibility behavior of an enterprise has a certain influence on the internal governance, and the internal governance will affect the overall level of enterprise governance through the ownership mechanism, the board supervision mechanism and the operator incentive mechanism, thereby affecting the growth of their performance. On the basis of this observation, this paper puts forward the following hypothesis:

Hypothesis 4: In the impact of social responsibility on manufacturing growth, the internal governance plays an intermediary role.

## 3. Research design

*3.1. Research framework*

After reviewing the related theories and putting forward the hypothesis, the research framework of this paper is shown in Figure 1. The independent variable of the structure is social responsibility, the medium variable is internal governance and the dependent variable is manufacturing growth.

*3.2. Sample selection and data collection*

Under the assistance of Shanghai Municipal Science and Technology Commission, Shanghai Business Association, Anhui Business Association, Shanghai Automotive Industry Corporation, Tongji University

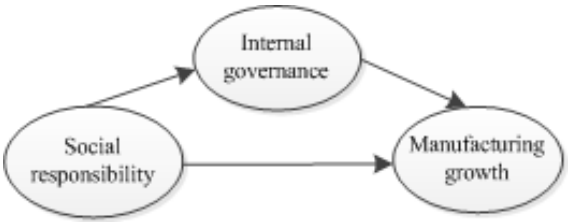


Figure 1. Framework of this paper

MBA project, University of Science & Technology of China MBA center and other units, carrying out this research has taken nine months from pre-investigation to the questionnaire revision by expert at the end of the formal research. Three kinds of investigation methods have been used: ① sending questionnaires by e-mail according to business yellow pages; ② researchers making an appointment with enterprises senior managers and filling in questionnaires face to face; ③ asking the employees of randomly selected sample enterprises who were also MBA students of Tongji University or University of Science & Technology of China, to fill in paper questionnaires in classroom and take them back on the spot.

In the period from September 2014 to May 2015, 500 questionnaires were distributed and 301 questionnaires were returned, only 251 questionnaires were valid, so the total recovery rate was 60.2% and the effective questionnaire recovery rate was 50.2%. As far as the type of manufacturing is concerned, the sample distribution is as follows: Food manufacturing has 97 (19.4%), Tobacco manufacturing has 83 (16.6%), Textile manufacturing has 70 (14%), Furniture manufacturing has 60 (12%), Paper product manufacturing has 35 (7%), Chemical products manufacturing has 31 (6.2%), Metal products manufacturing has 29 (5.8%), General equipment manufacturing has 16 (3.2%), and Automobile manufacturing has 79 (15.8%). Regarding the amount of capital, the sample distribution as follows: 1 billion Yuan or more has 115 (23%), 500 million -1 billion Yuan has 53 (10.6%), 100 million -500 million Yuan has 46 (9.2%), 50 million -100 million Yuan has 37 (7.4%), 10 million -50 million Yuan has 68 (13.6%), 181 have less than 10 million Yuan 181 (36.2%). In the case of the total number of employees, the sample distribution is as follows: over 1000 people have 155 (31%), 501 to 1000 people have 48 (9.6%), 201 to 500 people have 76 (15.2%), 101 to 200 people have 56 (11.2%), less than 100 people have 165 (33%).

*3.3. The operational definition and measurement of variables*

In order to ensure the validity and reliability of the measurement tool, this paper will adopt the scale which has been used in the international literature. Before the questionnaire was formally finalized and investigation, we had conducted a preliminary investigation on some experts and managers in order to evaluate the accuracy of questionnaire and language, then modified the questionnaire according to the re-

sults. We have used Likert scale in designing the questionnaire.

(1) Social responsibility. This paper argues that the social responsibility is the responsibility of manufacturing towards the internal and external stakeholders. The existing social responsibility measurement methods include: the measurement based on annual report content analysis (Bowman, 1975; Ingram, 1978; Preston, 1978; Abbott, 1979; Anderson, 1980); the measurement based on pollution index (Griffin, 1997); the perception measurement based on questionnaire survey (Aupperle, 1985; Maignan, 2000); the measurement based on reputation index (Wokutch, 1991; Moskowitz, 1972), and the measurement based on professional organization database (such as KLD, PIRC, IMUG) (Marquez & Fombrun, 2005). The main advantage of the perception measurement based on questionnaire survey is that its operation is very simple and the object of the survey is individual which does not necessitate the use of high cost multi-source information. The corporate citizenship measurement tool has been developed by Isabelle Maignan. It is very popular in practice and shows good psychometric characteristics (Maignan, Ferrell, 2000). In this paper, the measurement scale of the social responsibility employed the modified questionnaire which comes from Maignan and Ferrell et al. The social responsibility will be from two sub–dimensions, i.e. responsibility for the internal stakeholders (including 5 question items) and responsibility for the external stakeholders (including 6 question items).

(2) Internal governance. On the basis of the internal governance mechanism proposed by Xu (2006), this paper defined the internal governance as: implementation of governance to the agent, so as to carry out a set of property rights system arrangement of residual control and residual claim rights among the various interests of a company. On the basis of the study conducted by Xu (2006) and Hermalin (2000), we will divide the internal governance into three dimensions: the ownership mechanism, the board supervision mechanism and the operator incentive mechanism. Each dimension includes 3 question items.

(3) Manufacturing growth. The growth of manufacturing is mainly concerned about the operation and development of manufacturing industry in a certain period of time. Its evaluation mechanism in the existing literature is generally used as a market performance evaluation mechanism. On the basis of the existing manufacturing growth evaluation system, this paper takes the annual financial report data as the basis, selects the scale expansion ability index to reflect the manufacturing growth quantity characteristics, and selects the profitability growth and operational level improve index to reflect the manufacturing growth quality characteristics. Among them, the characteristics reflecting manufacturing growth include 3 question items: the employee's number growth rate, the owner's equity growth rate and the fixed asset growth rate; reflecting the quality characteristics of manufacturing growth includes 3 question items too: growth of accounts receivable turnover rate, growth of inventory turnover rate and growth of cash and its equivalent turnover rate.

### *3.4. Reliability and validity analysis*

As shown in Table 2, the consistency coefficient of the social responsibility, internal governance and manufacturing growth are 0.879, 0.843 and 0.872 respectively, the Cronbach's variables are all more than 0.7, the total scale is 0.942. Therefore, the reliability of each sub-scale and total scale is good, and the scale has good reliability as well.

This paper uses exploratory factor analysis and confirmatory factor analysis to test the content validity and construct a validity of measuring tool. The exploratory analysis results related to social responsibility, internal governance and manufacturing growth were shown in table 3. KMO of three variables are 0.832, 0.757, 0.856 respectively. Barlett Test of Sphericity is 0.000 (***). The results show that the effect is good and the next factor analysis can be carried out.

In order to further guarantee the validity of measurement tool, we use AMOS17.0 statistical software for conducting data confirmatory factor analysis. We mainly make a model suitability test based on the measurement pattern to test whether the variable has enough convergent validity. Bagozzi &Yi (1988) thought the ideal numerical range of fitness index is: GFI, CFI are more than 0.9 (0.8 can also be accepted); RMR is less than 0.05; RMSEA should be less than 0.05 (0.08 can also be accepted), the results were shown in table 4.

As can be seen from table 4 the model validation index of the questionnaire was at an acceptable level, which indicated that the questionnaire had good construct validity.

## 4. Data analysis and results

### *4.1. Correlation analysis*

After inspecting the construct validity of each subscale, we investigated the correlation between variables first in order to reveal the intensity of statistical relation, and to provide a basis for further description of the relationship. The average, standard deviation and correlation coefficient of each scale were statistically analyzed and the results were shown in Table 5.

As can be seen from table 5, there is a significant correlation between the variables.

### *4.2. Structural equation model analyses*

In order to explain the influence of two sub-dimensions of social responsibility (responsibility for the internal stakeholder and responsibility for the external stakeholder) on the internal governance and manufacturing growth and the different intermediary po-

Table 2. Cronbach's α of the variable

| Category of subscale | | Cronbach's α | |
|---|---|---|---|
| Social responsibility（11） | responsibility for internal stakeholders（5） | 0.879 | 0.852 |
| | responsibility for external stakeholders（6） | | 0.866 |
| Internal governance（9） | ownership mechanism（3） | 0.843 | 0. 920 |
| | board supervision mechanism（3） | | 0. 758 |
| | operator incentive mechanism（3） | | 0. 761 |
| Manufacturing growth（6） | | 0. 872 | |

Table 3. KMO and Bartlett's

| KMO and Bartlett's | | Social responsibility | Internal governance | Manufacturing growth |
|---|---|---|---|---|
| Kaiser-Meyer-Olkin Measure of Sampling Adequacy | | 0. 832 | 0. 757 | 0. 856 |
| Bartlett's Test of Sphericity | Approximate chi square distribution | 1171. 443 | 1002. 258 | 605. 226 |
| | Degree of freedom | 56 | 37 | 16 |
| | significance probability | 0. 000 | 0. 000 | 0. 000 |

Table 4. Confirmatory factor analysis results

| Fit index | $x^2$/ df | GFI | CFI | TLI | RMR | RMSEA | NFI |
|---|---|---|---|---|---|---|---|
| Social responsibility | 1.103 | 0.952 | 0.967 | 0.967 | 0.024 | 0.029 | 0.914 |
| Internal governance | 1.715 | 0.959 | 0.975 | 0.970 | 0.026 | 0.070 | 0.923 |
| Manufacturing growth | 1.677 | 0.905 | 0.947 | 0.901 | 0.044 | 0.074 | 0.934 |

Table 5. Statistical description and Correlation between research variables

| | 1 | 1.1 | 1.2 | 2 | 2.1 | 2.2 | 2.3 | 3 |
|---|---|---|---|---|---|---|---|---|
| 1 Social responsibility | 1 | | | | | | | |
| 1.1 responsibility for internal stakeholder | 0.832*** | 1 | | | | | | |
| 1.2 responsibility for external stakeholder | 0.851*** | 0.442** | 1 | | | | | |
| 2 Internal governance | 0.689** | 0.597** | 0.579** | 1 | | | | |
| 2.1 ownership mechanism | 0.418** | 0.346** | 0.364** | 0. 752*** | 1 | | | |
| 2.2board supervision mechanism | 0.600** | 0.519** | 0.501** | 0. 767*** | 0.337** | 1 | | |
| 2.3 operator incentive mechanism | 0.597** | 0.530** | 0.483** | 0. 764*** | 0.333** | 0.485** | 1 | |
| 3 Manufacturing growth | 0.635** | 0.545** | 0.535** | 0.673** | 0.451** | 0.518** | 0.594** | 1 |
| mean | 3.67 | 3.76 | 3.60 | 3.56 | 3.40 | 3.63 | 3.64 | 3.15 |
| standard deviation | 0.66 | 0.78 | 0.71 | 0.66 | 0.67 | 0.77 | 0.66 | 0.58 |

Note: ***indicates P＜0.001，**indicates P＜0.01，*indicates P＜0.05

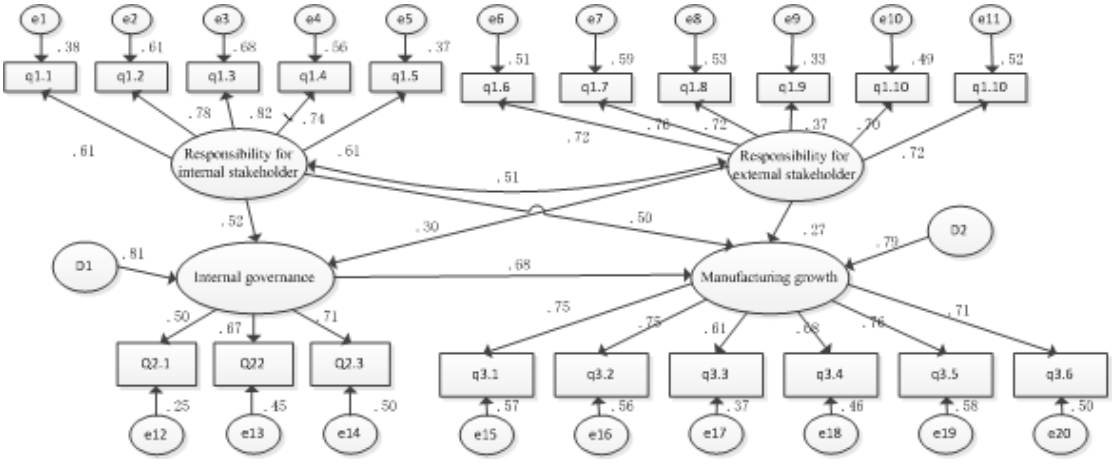


Figure 2. First order mediation model

Table 6. Fitting index of First order mediation model

| Fitting index | $x^2$/df | CFI | RMSEA | AIC | ECVI |
|---|---|---|---|---|---|
| Criterion | <5 | >0.90 | <0.08 | As small as possible | As small as possible |
| Default model | 1.918 | 0.920 | 0.051 | 437.385 | 0.842 |
| Saturated model | - | 1.000 | - | 449.000 | 0.899 |
| Independence model | 11.564 | 0.000 | 0.198 | 2459.741 | 8.199 |

Table 7. Path coefficients and the verification results of hypothesis

| Paths | estimated value | standard value | S E | C R | P |
|---|---|---|---|---|---|
| Internal governance←responsibility for internal stakeholder | 0.642 | 0.516 | 0.072 | 5.978 | *** |
| Internal governance←responsibility for external stakeholder | 0.735 | 0.500 | 0.061 | 6.171 | *** |
| Manufacturing growth←Internal governance | 0.748 | 0.584 | 0.584 | 2.774 | 0.004 (**) |
| Manufacturing growth←responsibility for internal stakeholder | 0.485 | 0.303 | 0.303 | 2.091 | 0.033 (*) |
| Manufacturing growth←responsibility for external stakeholder | 0.336 | 0.272 | 0.272 | 3.088 | 0.040 (*) |

sition and role of intermediate variable's (internal governance) on the two sub-dimensions, we establish a first order mediation model containing the two sub-dimensions especially. According to the existing literature, we use AMOS17.0 software to establish a structure model including 4 latent variables (responsibility for the internal stakeholder, responsibility for the external stakeholder, internal governance, and the manufacturing growth). The above-mentioned analysis of the reliability and validity shows that both these factors are acceptable for all 4 latent variables. Therefore, in this paper, for the purpose of measuring the internal governance, we take the mean score of the first level factor as the factor score at first, and then take the first level factor as the multiple measure index of the second level variable. Specifically, we adopt the mean score of each factor in questionnaire as the index of potential variables. The overall analysis model is shown in Figure 2 (the potential variable is represented by an ellipse, and the observed variable is represented by a rectangle).

The main fitting index of the model is shown in table 6. We can see that the score of $x^2$/ df is 1.918, far less than the acceptance criteria score of 5; CFI is 0.920, greater than the acceptance criteria 0.90; RMSEA index is 0.051, less than the acceptance criteria 0.08; information index AIC and ECVI are smaller than the score of Saturated model and Independence model, comply with the index evaluation criteria. The overall fitting of the model is good, so the structural equation modeling is acceptable and model does not need to be corrected.

Estimated parameters of internal governance and manufacturing growth have all passed the test. Among the impact path, the completely standardized effect value of responsibility for internal stakeholder and internal governance is 0.516 ($P<0.001$), thus passing the significance test; the completely standardized effect value of responsibility for external stakeholder and internal governance is 0.500 ($P<0.001$), and passes the significance test too; the results indicate that there is a significant positive relationship between the two sub-dimensions of the social responsibility and the internal governance. The completely standardized effect value of the internal governance and manufacturing growth is 0.584 ($P=0.004<0.05$), passing the significance test, and showing that there is a significant positive relationship between the internal governance and manufacturing growth; the completely standardized effect value of responsibility for internal stakeholder and manufacturing growth is 0.303 ($P=0.033<0.05$), passed the significance test as well; the completely standardized effect value of responsibility for the external stakeholder and manufacturing growth is 0.272 ($P=0.040<0.05$), passed the significance test too, thus indicating that there is also a significant positive relationship between the two sub-dimensions of the social responsibility and manufacturing growth. All the calculated results were shown in Table 7.

## 5. Results discussion and implications for manufacturing growth

On the basis of combining the relevant literature, this paper first presents a model for analyzing the relationship between the social responsibility (including the responsibility for the internal stakeholder and responsibility for the external stakeholder), the internal governance and the manufacturing growth (inclu-

ding the ownership mechanism, the board directors mechanism and the operator incentive mechanism), and puts forward the corresponding research hypothesis. Then, statistical software was used to collect the data from 500 manufacturing enterprises in East China and verify the proposed hypothesis, as well as the expected results.

Now we will discuss the study results in-depth in order to trigger more thinking and provide inspiration.

*5.1. Results discussion*

Through testing and verifying the relationship model of the social responsibility and the manufacturing growth, we found that the completely standardized effect value of social responsibility and manufacturing growth is 0.871 ($P<0.001$) thus passing the significance test. This indicates that the positive correlation between the social responsibility and the manufacturing growth is significant, which supports the hypothesis 1. Taking responsibility for the internal stakeholder and the external stakeholder as potential variables to built a relationship model of the potential variables and the manufacturing growth, we also found – through testing and verifying the relationship model – that the completely standardized effect value of responsibility for the internal stakeholder and manufacturing growth is 0.402 ($P < 0.001$), whereas the completely standardized effect value of responsibility for the external stakeholder and manufacturing growth is 0.412 ($P<0.001$). These values have a high level significance, showing that potential variables have a significant positive effect on manufacturing growth which strongly supports the hypothesis 1-1 and hypothesis 1-2.

The completely standardized effect value of social responsibility and the internal governance is 0.772 ($P=0.009<0.01$) passing the significance test, and showing that take social responsibility has a significant positive effect on the internal governance and confirms the hypothesis 2. These results of the empirical analysis are consistent with the partial view of Maignan and Ferrell. Although the social responsibility is a common phenomenon, using it to achieve sustainable development is a difficult thing. Therefore, effectively managing the social responsibility behavior in the manufacturing industry to promote the internal governance mechanism and improve their competitive advantages is a problem worthy of further exploration.

The completely standardized effect value of the internal governance and the manufacturing growth is 0.570 ($P=0.007<0.01$), which is enough to pass the significance test, and shows that the internal governance has a significant positive effect on the manufacturing growth, which confirms the hypothesis 3. The results of this empirical analysis are consistent with view of Xu (2006). In recent years, due to the development of a harmonious society, manufacturing is increasingly dependent on the social responsibility to realize the added value and establish competitive advantage, so we should pay more attention to the social responsibility effect on the internal governance process in the course of research on the manufacturing growth, and put focus on the effect path, analysis and description of the impact path carefully to find out the method of improving the manufacturing growth efficiency.

In the structural equation, there are two paths of social responsibility influencing the manufacturing growth. The first path is social responsibility having a direct impact on manufacturing growth, in this path, the completely standardized effect value is 0.871 ($P<0.001$) and the direct effect value is 0.413 ($P=0.09<0.01$). The other path of social responsibility influencing manufacturing growth is through the internal governance, the indirect effect value is 0.440 (the completely standardized effect value of social responsibility and internal governance is 0.772, $P<0.001$; the completely standardized effect value of the internal governance and manufacturing growth is 0.570, $P=0.07<0.01$). In this path, the internal governance is an intermediary variable between social responsibility and manufacturing growth. The indirect effect produced by intermediate variable is greater than the direct effect of social responsibility on manufacturing growth. Therefore, the internal governance will enlarge the influence of social responsibility on manufacturing growth, and this result confirms the hypothesis 4.

*5.2 Implications for manufacturing growth*

Undertaking social responsibility is a means for modern manufacturing to obtain competitive advantage. Through assuming social responsibility, the manufacturing industry can meet the stakeholders' requirements efficiently, establish a high quality relationship with them and finally obtain the competitive advantage. As far as the methods of acquiring competitive advantage are concerned, there is no essential difference between the social responsibility behavior and other means. Within the stakeholder theory framework, the social responsibility of manufacturing is not only the responsibility for shareholders, but for all stakeholders, including shareholders, managers, general staff and other internal stakeholders, as well as the responsibility for consumers, suppliers, creditors, distributors, government, natural environment, community and other external stakeholders. However, whether it is to bear responsibility for the internal stakeholders or for the external stakeholders, faced with rising society expectations, the manufacturing enterprises should actively seek for the compromise between their own interests and social interests, through taking the social responsibility to reduce risks, improve the reputation, and increase the opportunities. The essence of social responsibility behavior is the adjustment of the management mechanism. When the ownership mechanism, the board supervision mechanism and the operator incentive mechanism are beneficial to

the development strategy and policy, the enterprise social responsibility performance will be more and more obvious. Therefore, establishing internal governance mechanism with bidirectional substitution effect is the only efficient way to improve the social responsibility behavior in industry.

In the actual operation process of manufacturing, the internal governance and social responsibility are all in crucial position, as they are indispensable in mutual promotion and mutual transformation. From the perspective of value creation, they are the core resources of enterprises, which should be combined consciously and promote sustainable development of an enterprise through *integration*. Many aspects of the internal governance have significant effects on the manufacturing growth performance. Among them, the ownership mechanism, the board supervision mechanism and the operator incentive mechanism have a significant promoting role. Therefore, improving the ownership mechanism, strengthening the board supervision mechanism and enhancing the operator incentive mechanism all have become a reasonable choice to guarantee the efficient performance of social responsibility and improvement in the manufacturing growth.

**References**


1. ABBOTT W.F., MONSEN J., 1979, On the Measurement of Corporate Social Responsibility: Self- Reported Disclosures as a Method of Measuring Corporate Social Involvement, in: *Academy of Management Journal*, vol. 22, no 3, p. 501-515.
2. AKIYOSHI H. HANAZAKI M.-H., 2004, Governance structure of Japanese companies, in: *Economic and management research*, no 1, p. 95-101.
3. ANDERSON J.C., FRANKLE A.W., 1980, Voluntary Social Reporting: An iso-beta Portfolio Analysis, in: *The Accounting Review*, vol. 55, no 3, p. 467-479.
4. AUPPELE K.E., CARROLL A.B., HATFIELD J.D.,1985, An Empirical Examination of The relationship between Corporate Social Responsibility and Profitability, in: *Academy of Management Journal*, vol. 28, no 2, p. 446-462.
5. BAGOZZI R.P., YI Y., 1988, On the evaluation of structural equation models, in: *Academy of Marketing Science*, vol. l16, no 1, p. 74-94.
6. BAYSINGER B., BUTLER H., 1985,Corporate Governance and the Board of Directors: Performance effects of Changes in Board Composition. Journal of Law, in: *Economics and Organization*, vol. 1, no1, p.101-124.
7. BHAGAT S., BLACK B., 2002,The Non-Correlation Between Board Independence and Long-Term Firm Performance, in: *Journal of Corporation Law*, no 27, p. 231-273.
8. BLAIR M.M., 1995, Corporate 'Ownership', in: *The Brookings Review*, vol. 13, no1, p. 16-19.
9. BOWEN H.R., 1953, *Social Responsibilities of the Businessman*, HarPer&Row, New York.
10. BOWMAN E.H., HAIRE M.A,1975, Strategic Posture toward Corporate Social Responsibility, in: *California Management Review*, vol. 18, no 2, p. 58-68.
11. BRAMNRNER S..WILLIAMS G.,ZINKLN,J., 2007, Religion and Attitudes to Corporate Social Responsibility in a Large Cross-Country Sample, in: *Journal of Business Ethies*, vol. 71, no 3, p. 229-243.
12. CARROLL A.B., 1979, A Three-Dimensional Conceptual Model of Corporate Performance, in: *Academy of Management Review*, vol. 4, no 4, p. 497-505.
13. CHANG K., 2004, Put corporate social responsibility movement in our country's labor law track, in: *Chinese party and government cadres Forum*, no 3, p. 25-28.
14. CHEN Y.S., LIN M.J., CHANG C.H., 2009, The positive effects of relationship learning and absorptive capacity on innovation performance and competitive advantage in industrial markets, in: *Industrial Marketing Management*, vol. 38, no 2, p. 152-158.
15. CHENG H., XIN Y., 2003, The capital structure, enterprise scale and enterprise growth of Chinese science and technology enterprise, in: *Journal of world economy*, no 12, p.72-75.
16. CHENG X.,WANG H., 2004, Equity balance and corporate value: model and empirical evidence, in: *Quantitative economic technology and Economic Research*, no 11, p. 102-110.
17. CHENG Z., 2006, Research on the independent innovation strategy of agricultural equipment manufacturing industry, in: *Agriculture Machinery Technology Extension*, no 8, p. 8-11.
18. CLARKSON M.E.1995,A Stakeholder Framework for Analysing and Evaluating Corporate Social Performance, in: *Academy of Management Review*, vol. 20, no 1, p. 92-11.
19. DIANE D.K., MCCONNELL J., 2003, International Corporate Governance, in: *Journal of Finacial and Quantitative Analysis*, vol. 38, no 1, p. 1-36.
20. DING Y. D., 2010, *China's manufacturing industry's upgrade facing the global industry value chain*, Science Press, Beijing.
21. DUNNE P., HUGHES A., 1992, Age, Size, Growth and Survival Revisited, in: *Small Business Research Centre*, University of Cambridge.
22. FREDERICK W.C., 1994, From CSRI to CSRZ: The Maturing of Business-and-Society thought, in: *Business and Society*, vol. 33, no 2, p. 150-164.

23. GAO L., SONG S., *Executive stock ownership and corporate performance – based on the Listing Corporation from 2000-2004*, p.134-143.
24. GREENLY G.E., FOXALL G.R., 1997, Multiple Stakeholder Orientation in UK Companies and the Implications for Company Performance, in: *Journal of Management Studies*, vol. 34, no 2, p. 59-284.
25. GRIFFIN J.J., MAHON J.F., 1997, The Corporate Social Performance and Corporate Financial Performance Debate Twenty G five Years of Incomparable Research, in: *Business&Society*, vol. 36, no1, p.5-31.
26. GUNGOR A., GUPTA S.M., 1999, Issues in environmentally conscious manufacturing and product recovery: a survey, in: *Journal of* computers *& industrial engineering* , vol. 36, no 4, p. 811-853.
27. HAN S., LI K., 2005, Research on the international transfer of iron and steel industry, in: *Journal of Northeastern University (Social Science)*, no 5, p. 5-10.
28. HIDEAKI M., NITTA K., SAITO N., YUSUKE O., 2004, Enterprise management efficiency and corporate governance, in: *NLI Research Institute report*, vol. 33, no 3, p.52-98.
29. HOLMSTROM B.R., MILGROM P., 1991, Multitask Principal-Agent Analyses: Incentive Contracts, Asset Ownership and Job Design, in: *Journal of Law, Economics and Organization*, no7, p. 24-52.
30. ILGIN M.A.,GUPTA S.M., 2010, Environmentally conscious manufacturing and product recovery (ECMPRO): A review of the state of the art, in: *Journal of environmental management*, vol. 91, no 3, p.563-591
31. INGRAM R.W., 1978, An Investigation of the Information Content of (Certain) Social Responsibility Disclosures, in: *Journal of Accounting Research*, no 16, p. 270-285.
32. JIN L., 2006, Empirical Study on the evaluation index system of corporate social responsibility movement – consumer perspective, in: *China's industrial economy*, no 6, p. 114-120.
33. JONES T.M., Instrumental Stakeholder Theory A Synthesis of Ethics and Economics, in: *Academy of Management Review*, vol. 20, no 2, p. 404-437.
34. JU F., XIE Z., BAO G., 2005, Realization of corporate social responsibility based on consumer choice, in: *China Industrial economy*, no 9, p. 91-98.
35. KUROIWA I., OZEKI H., 2010, Intra-regional Trade between China, Japan, and Korea Before and After the Financial Crisis, In: *Ide Discussion Paper*, no 237.
36. LIN L., 2005, The industry analysis of the equity of the listing Corporation in China, in: *Industrial economy research*, no 6, p. 43-47.
37. LICHTENBERGER F.R., PUSHNER G.M., 1994, Ownership Structure and corporate performance in Japan, in: *Japan and World Economy*, no 6, p.239-261.
38. LI Z., 2006, Study on the relationship between corporate social responsibility and corporate value Empirical Evidence from Shanghai stock market listing Corporation, in: *China's industrial economy*, no 2, p. 77-83.
39. LU G., 2002, Research on innovation of recession industry, in: *Economic Issues in China*, no 5, p. 45-51.
40. MAIGNAN, FERRELL O.C., 2000, Measuring Corporate Citizenship in Two Countries: The Case of the United States and France, in: *Journal of Business Ethics*, vol. 23, no 3, p.283-297.
41. MERZ G.R., SAUBER M.H., 1995, Profiles of Managerial Activities in Small Firms, in: *Strategic Management Journal*, vol. 16, no 7, p.551-564.
42. MOSKOWITZ M.R., 1972, Choosing Socially Responsible Stocks , in: *Business & Society Review*, p.71-76.
*43.* NAGAR V., PETRONI K., WOLFENZON D., 2000, Ownership Structure and Firm Performance in Closely-Held Corporations, in:*Working Paper of University of Michigan Business School*, no 1, p. 50-57.
44. PESARAN M., HASHEM R., 1995 , Estimating Long-Run Relationships from Dynamic Heterogenous Panels, in: *Journal of Econometrics*, vol. 68, no1, p. 79-113.
45. PRESTON L.E.,1978, Comparing Corporate Social Performance: Germany, France, Canada and the U.S., in: *California Management Review*, vol. 20, no 4, p. 40-49.
46. QIAN Y., 1995, Corporate governance structure reform and financial structure reform, in: *Economic Research Journal*, no 1, p. 20-29.
47. DONKELS R., MIETTINEN A., 1997, Measuring growth: Methodological considerations and empirical results, in: *Entrepreneurship and SME research*, Ashgate, UK.
48. ROBERT R.W., 1992, Determinants of Corporate Social Responsibility Disclosure: an Application of Stakeholder Theory, in: *Accounting, Organizations & Society*, vol. 17, no 6, p. 595-612.
49. SHAH R., WARD P.T., 2003, Lean manufacturing: context, practice bundles, and performance, in: *Journal of operations management*, vol. 21, no 2, p. 129-149.
50. SHENG H., 2006, A review of the research on the corporate social responsibility of corporate social responsibility in the 21st Century, in: *Foreign economics and management*, vol. 28, no 8, p. l-9.
51. SONG Z., ZHANG Z., ZHU J., 2005, Analysis on the influence of the equity incentive of the

managers of the Listing Corporation, in: *Management review*, no 3, p. 3-8.
52. SUN H., 2006, *Research on corporate governance structure and company growth ability*, Jilin University.
53. SVENDSEN A., BOUTILIER R., ABBOTT R., WHEELER D., 2003, Measuring the Business Value of Stakeholder Relationships, *in: Stakeholder Relationships, Social Capital and Business Value Creation*. Research Report by Center for Innovation in Management (CIM) of Simon Fraser University, Schulich School of Business and Canadian Institute of Chartered Accountants (CICA).
54. TAKAFUMI S., YASUHIRO, Y.,2000,Corporate governance and shareholder's value, in: *Securities Analysts Journal*, no 9, p.28-46.
55. TIROLE J., 2001, Corporate Governance, in: *Econometrica*, vol. 69, no1, p. 1-35.
56. VACHON S., KLASSEN R.D., 2008, Environmental management and manufacturing performance: The role of collaboration in the supply chain, in: *International journal of production economics*, vol. 111, no 2, p. 299-315.
57. WADDOCK S.A., GRAVES A.B., 1997, The Corporate social Performance-Financial Performance Link, in: *Strategic Management Journal*, vol. 18, no 4, p. 303-319.
58. WADDOCK S.A.,GRAVES S.B.,1997,Quality of management and quality of Stakeholder relations:Are They Synonymous? in: *Business&Society*, vol. 36, no 3, p. 250-279.
59. WANG Q., HE S., 2005, Analysis of the main factors affecting the growth of Chinese Listing Corporation, in: *Journal of statistics and decision making*, no 1, p. 33-36.
60. WARD P.T., DURAY R., 2000, Manufacturing strategy in context: environment, competitive strategy and manufacturing strategy, in: *Journal of operations management*, vol. 18, no 2, p.123-138.
61. WHEELER D., COLBERT B., FREEMAN R.E. 2003, Focusing on Value: Reconciling Corporate Social Responsibility, Sustainability and a Stakeholder Approach in a network world, in: *Journal of General Management*, vol. 28, no 3, p. l-28.
62. WILLIAMSON O.E., 1975, *Markets and Hierarehies*, Fress Press, New York.
63. WOOD D.J., JONES R.E., 1995, Stakeholder Mismatching: A Theoretical problem In Empirical Research on Corporate Social Performnance, in: *International Journal of organizational Analysis(1993-2002)*, vol. 3, no3, p. 229-267.
64. WOOD D.J., 1991, Corporate social performance Revisited, in: *The Academy of Management Review*, vol. 16, no 4, p. 691-717.
65. WOKUTCH R.E, MCKINNEY E.W., 1991, Behavioral and Perceptual Measures of Corprorate Social Performance, in: Post J.E. (ed.), *Research in Corporate Social Performance and Policy*, no 12, p. 309-330.
66. WU M.L., 2006, Corporate Social Performance, Corporate Financial Performance and Firm Size: A Meta-Analysis, in: *Journal of American Academy of Business Cambridge*, vol. 8, no 1, p. 163-171.
67. XU L., XIN Y., CHENG G., 2006, The impact of ownership concentration and equity balance and its impact on the company's operating performance, in: *Economic research*, no 1, p. 90-100.
68. YANG L.., ZHAO C., 2010, Summary of Enterprise Growth Theory-Based on View of Growth Motivation, in: *Soft Science*, vol. 7, no 24, p. 106-110.
69. YAO Q., 2006, *Debt maturity structure, corporate performance and growth*, Dongbei Finance and Economics University.
70. YOU J., CHENG S., 2003, Advanced *management science*, Higher Education Press, Bejing.
71. ZHANG P., 2013, *Global value Chains specialization and China's manufacturing industries' growth.* Liaoning University.
72. ZHANG Q., 2003, The international competitiveness of China's manufacturing industry under the opening conditions, in: *Management World*, no 8, p. 74-79.
73. ZHOU X., 2004, Industry rise and fall of, in: *Journal of humanities*, no 7, p. 15.
74. ZHOU Z., 2005, Corporate social responsibility: perspective, form and connotation, in: *Theory Journal*, no 3, p. 14-24.
75. ZHU H.,WANG T., 2003, Study on the inner mechanism of the growth of modern enterprises, in: *Journal of Southern Yangtze University*, vol. 2, no 2, p. 63-69.

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# Prosumption as a factor of sustainable development

# Prosumpcja jako czynnik zrównoważonego rozwoju

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## Abstract

The article raises the issue of presumption as the increasingly widespread pattern of consumer behaviour leading to independence or the significant reduction of the use of some types of services and products on the market principles. It indicated the pro-ecological conditions of this group of consumer behaviours and their importance for the practical realisation of the concept of sustainable development. It reviewed the existing approaches concerning presumption and sustainable development. Taking into account the current state of knowledge, the concept of the prosument product was proposed, which can be treated as the involvement of citizens in the potential spheres of prosument actions to achieve sustainable development and providing the tangible and intangible benefits to people involved in its creation. It has also paid attention to the key areas of prosumption which impact the natural environment, also the potential courses of action were indicated, which should be taken by the state policy makers and the non-governmental organisations for the development of prosumer activity.

**Key words:** prosumption, prosumer, municipal services, sustainable development

## Streszczenie

Artykuł porusza zagadnienie prosumpcji jako coraz powszechniejszego wzorca zachowań konsumenckich prowadzących do uniezależnienia się lub znacznego ograniczenia korzystania z niektórych rodzajów usług i produktów na zasadach rynkowych. Wskazano uwarunkowania proekologiczne tej grupy zachowań konsumpcyjnych oraz ich znaczenie dla praktycznego zrealizowania koncepcji zrównoważoneo rozwoju. Dokonano przeglądu dotychczasowych podejść dotyczących prosumpcji i zrównoważonego rozwoju. Uwzględniając obecny stan wiedzy zaproponowano koncepcję produktu prosumenckiego, który można traktować jako zaangażowanie się obywateli w potencjalne sfery działań prosumenckich służących osiągnięciu zrównoważonego rozwoju oraz dających korzyści materialne i pozamatierialne osobom zaangażowanym w jego powstawanie. W artykule zwrócono także uwagę na kluczowe dziedziny prosumpcji mające wpływ na stan środowiska naturalnego oraz wskazano potencjalne kierunki działań, które powinni podjąć decydenci państwowi oraz organizacje pozarządowe dla rozwoju aktywności prosumenckiej.

**Słowa kluczowe:** prosumpcja, prosument, usługi komunalne, zrównoważony rozwój

### Introduction

Prosumption is a multidimensional phenomenon, which can be viewed from different perspectives. From a sociological perspective, it is seen as a phenomenon creating a new form of capitalist society based on prosumption, the so-called prosument society (Ritzer et al., 2012, p. 379-398). From the economic perspective, the attention is paid to the market dimension, related to its occurrence. Reference is made to its economic importance, e.g., the development of stores with products, which are used by consumers for creating the final product (shops with materials for handiwork). While the management perspective allows to treat it as a part of the company's strategy aimed at the cooperation with customers during production and sale of consumer goods and services. In this sense, prosumption means initiating

and including the customer into cooperation in the creation of the final product. This is done by preparing a standardised product or service, which then can be adapted by the consumer to own needs. By doing so, the long-term loyalty of consumers is built. Therefore, prosumption becomes a factor strengthening the competitive position of the company on the market (Michale, 1997). In turn, the technical perspective pays attention to technical solutions used in presumption, e.g., in the energy sector (Bremdal, 2011, p. 1-25). These approaches indicate various aspects of the occurrence of prosumption in the economy and society.

**Prosumption and prosumer**

The word *prosumer* is a neologism made up of the words *producer* and *consumer*. For the first time this term was characterised by Toffler (1981) in his book *The third wave*. According to Toffler, there is a change of the society and consumers. Some of them change into manufacturers of certain goods and services in different time periods related to the socio-economic development. He called these periods the waves. He defined their three types. In the first wave, agriculture played a dominant position. According to Toffler, in this period, most people were *prosumers* and produced mainly food (cultivating the land and dealt with crafts peripherally) for their own needs. During this period, the people were the producer and consumer at the same time of what they created. In the second wave, which emerged with the industrial revolution at the end of the 18$^{th}$ century, the factory became a dominant institution. During this period, most people worked in factories (and spent most of their time in them). This type of situation led to the inability to manufacture certain services and products for their needs. This resulted in the cessation of activities of the prosumption nature accompanying the first wave, and instead the consumption on a large scale started to emerge. The next post-industrial period related with the so-called third wave according to Toffler, is characterised by the re-withdrawal to prosumption. In contrast to the motives of prosumption in the first wave, the desire for individuality and diversity of customers is a motive of prosumption (Toffler, 1981). Prosumption accompanying it offers the opportunity to express own individuality and meeting the growing diversity of customers' needs and requirements (Gilmore & Pine, 1996).

Therefore, the consumer takes a more active role and becomes an experienced business partner (Gibbert, Leibold, and Probst, 2002). Currently, companies have in mind that the customers are becoming active, well-informed and constitute a part of the organisation (Prahalad & Ramaswamy, 2004). Customers' ideas, suggestions and complaints are used as a driving force for innovation (Mazur & Archakova, 2011). Since there is no clear definition of the prosumer term, in literature we can find different grasps, which are trying to determine the consumer's involvement before the proper process of product purchase or after it in the context of meeting his needs. This problem fits in the issues related to prosumption.

A. Toffler has rejected the traditional concept of the binary consumer, indicating the creation of a new type of consumer, who is involved in the search of products which best fit his expectations. Toffler, forecasting the role of a producer and consumer in the future, pointed to the emergence of a new role, which he called presumption (Toffler, 2006). In this understanding, production and consumption are elements of the same cycle. The value is generated when consumers make an effort and pay attention to the products *produced* by themselves (van Raaij, 2001, p. 332). While prosumption is a process, and not a single act. It involves the integration of the physical and mental activity with the socio-psychological experience. People participating in this process involve money, time, effort and skills, expecting certain benefits (Lebiejko, 2011, p. 65). The Toffler approach has become an inspiration for many researchers, who have modified this concept, adapting it to the changing economic and social conditions. Relations of the producer with the consumer are undergoing changes. Kotler (1986) refers to the prosumer concept from the marketing point of view. Because the so-called third wave is characterised by de-industrialisation, moving away from the mass production and demarketisation, these phenomena result in the consequences for the studies and practices of marketing. Kotler summarises the views of Toffler with reference of their results to marketing (see table 1).

According to Kotler, the forces which will foster the development of prosumption include: the growing work costs, structural unemployment, demand for goods and higher quality services, development of new technologies enabling people to take part in designing non-standard goods, as well as the general increase of education. Kotler also indicates the conditions inhibiting prosumption. They threaten the interest groups, e.g., like professionals, manufacturers of some goods and services, and labour unions. These entities can take the protectionist measures to slow down the development of prosumption striving for the beneficial legal laws, like e.g., the construction regulations (PIHL, 2008).

Prosumers look for values provided by products and services, which provide benefits in terms of saving time, money, energy (see figure 1). They also expect that producers will provide them with products at the lowest possible prices and without additional hidden costs. They are also interested in environmentally friendly products. There are also pragmatic users of products, for whom the modern technologies and en-

Table 1. Chart by Kotler (1986) summarising Toffler's main ideas

| | Thesis<br>First Wave | Antithesis<br>Second Wave | Synthesis<br>Third Wave |
|---|---|---|---|
| Dominant institution | Agriculture | Industry (factory) | Home |
| Mix of prosumers & consumers | Many prosumers (Sector A is large)<br>Few consumers (Sector B is small) | Few Prosuments (Sector A is small)<br>Manmy consumers (Sector B is large) | More prosuments (Sector A gets larger)<br>Fewer consumers (Sector N gets smaller) |
| Dominant processes | Self-production | Industrialization, Marketialization | De-industrialization<br>De-marketization<br>De-massification |
| Norm | Survival | Efficiency (as producers)<br>Indulgence (as consumers) | Idividuation |
| Social nexus | Kinship and friendship; tribe | Conctracts and transactions: workplace | Family and friends; neighbourhood |

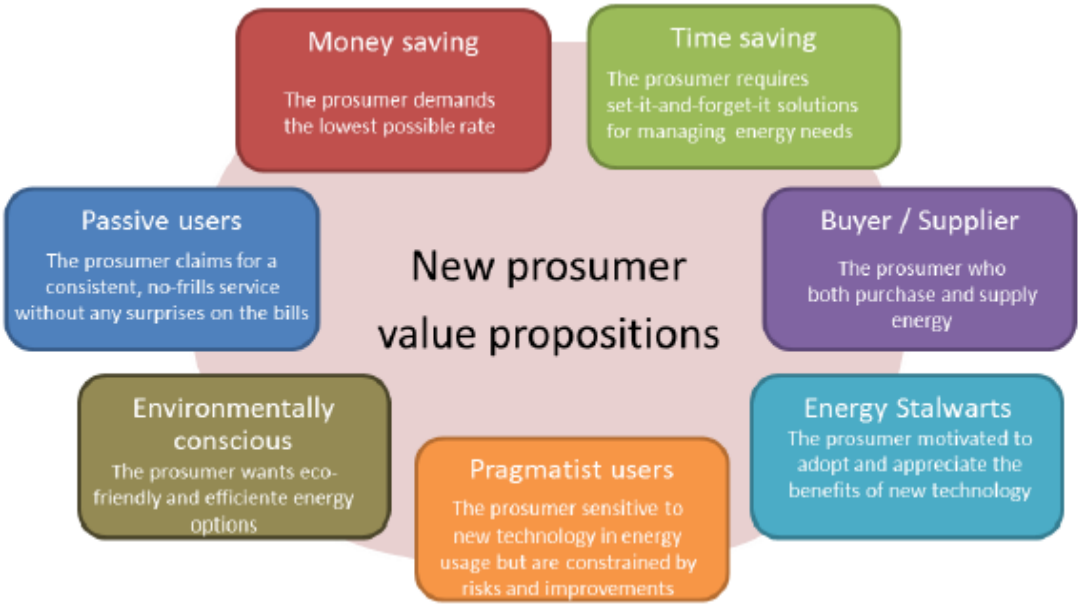


Figure 1. New prosumer value propositions, source: Rodriguez-Molina et al., 2011

ergy use related to their use are important. The changes introduced by manufacturers in the future product versions are also important to them.

The discussed concepts take the active participation of people in the production of the consumer goods as the starting point, which is characterised by the uniqueness and adjustment to their expectations. Consumers engaged in activities for the new product are the co-authors of the new value. This most often takes place in the area of mass media. The idea of prosumption in creating new values was presented in an interesting way by A. Bruns, while analysing the communication process in Web 2.0, has indicated the creation of the so-called produsage, that is a person, who plays a hybrid role between the user and producer (Bruns, 2008, p. 21). Its role is the continuous construction and the expansion of the already existing contents for the further improvement. The products of the produsagers work are not separate products nor they create directly new products, but they create a new intangible value. An important feature of this type of consumers is to share knowledge and its continuous improvement. A produsage using open source technologies, is a creator and at the same time a user of the contents in different Internet environments, such as Wikipedia, Second Life, blogs, social networks, e.g., You Tube MOVEN, Flickr, etc. By sharing experiences and knowledge with others, he creates the identity and symbolic value of the new product (Majboub, 2014, p. 12-31). The idea of produsage is used in computer games, in which the player is often both the user and the co-creator. From the studies of A. Tolino on prosumption in computer games it results that producers of computer games often encourage players to modify their products, so they are more attractive also for other users. Players become co-producers of games, introducing new solutions, new game elements, what often determines the success of the given game on the market (Tolino, 2010, p. 339-369).

## Ecological conditions for presumption

Reducing emissions and the desire to limit the impact of the investment on the environment – especially in the European Union – is a megatrend realised consequently for over 20 years. It aims to counteract the climate changes and reduction of the impact of other harmful emissions on the environment. It is associated with the model of development of the European Union, where an important growth driver includes innovations, investments in green technologies and the improvement of effectiveness. Reduction of emissions from the energy sector subject to the EU legislature concerns not only the limitation of the greenhouse gas emissions (including $CO_2$), but also the limitation of low emissions and all air pollutions (Polish energy sector...., 2011).

Greenhouse gas emissions (including $CO_2$ and the ways to reduce them have been the socially and politically supported subject for several decades. This is dictated by the trend visible in the international politics and legislation for years, which concerns sustainable development, environmental protection, prevention of air pollution and climate changes. Democratic societies, especially in the densely populated Europe, are trying to improve the environment – especially in their immediate surroundings (Polish energy sector ..., 2016).

Recognition of the problems associated with the progressive degradation of the natural environment and the increase in scarcity of its resources, over time has forced the changes both in the ways of managing the natural environment and its resources, as well as in the socially accepted value systems and the associated lifestyles. In the sphere of consumption it meant the emergence of a new trend, defined as the greening of consumption, eco consumption, ecological consumption or sustainable consumption.

According to the European Environmental Agency, sustainable consumption is defined as: the holistic approach aimed at minimising the impact of social production and consumption systems on the natural environment. The objective of sustainable consumption is to maximise the efficiency and performance in terms of the production and delivery of products, services and investments so as to meet the current needs of societies without reducing the possibilities of future generations to meet their needs (State of the environment, 2007).

Sustainable consumption is the optimal, conscious and responsible use of the available natural resources, goods and services at the level of individuals, households, communities and local communities, business communities, local governments, national governments and international structures, in accordance with the principles of sustainable development. The attitude of sustainable consumption means less waste, production of waste and pollution, and the selection of goods and services, which to the greatest extent meet certain ethical, social and environmental criteria (Through sustainable consumption, 2012).

Consumers in highly developed societies increasingly reveal their ecological awareness, hence the growing interest in eco consumption and eco industry. They become more sensitive to the damages caused to the environment in the process of using the products. They realise that their actions can cause external side effects not only in the local dimension, but also the global one, because one of the effects of mass consumption is the huge mass of post-consumer waste, which is equally harmful like the post-production one (Bywalec, Rudnicki, 2002, p. 130).

Prosumer initiatives related to the use of the renewable energy sources are one of the key actions of the horizontal policy of the European Union in terms of climate protection, energy safety and environmental protection. Reducing emissions of harmful substances (mainly greenhouse gases), the positive impact on the safety of energy supply and effective use of energy are important factors for the development of the domestic energy systems (Bańkowski, Żmijewski, 2012, p. 13).

## Prosumption and the bases for sustainable development

In general, we can talk about two basic approaches to sustainable development. The first approach is practical-economic (economic) and is identified with the paradigm of protection and environment management. In this sense, sustainable development is perceived as agreement of the traditional economic growth with the ecological conditions. The second look at sustainable development has the ideological and historiosophical nature. This understanding challenges the current models of civilisation development and focuses on searching for new behaviours and social goals, and in their context the new forms of civilisation development. Sustainable development holistically recognises the individual elements of civilisation. It includes the management of natural, economic and human resources, spatial management, institutional solutions, moral sphere, shaping the awareness or the selection of specific lifestyle. In fact, it is about searching and formulating the new, ecologically optimal and socially satisfactory vision of civilisation (Piontek, 2002, p. 51).

The essence of sustainable development is to seek to connect the ecological, economic and social accounts. The mechanism of functioning of this global concept is brought down to the achievement of three basic goals:

1) ecological – consisting of stopping the environmental degradation and elimination of its threats,
2) economic – expressed in the satisfaction of the basic material needs of the people using the

technique and technology that do not damage the environment, and

3) social and humanitarian – which assumes the security of the social minimum (ending hunger, misery and poverty), health protection, development of the spiritual sphere of the man (culture), safety and education (Machowski, 2003, p. 100-101).

The increasing awareness of responsibility for the global scale of environmental changes generated even by the individual actions of the man has led to searching for such a model of development, which will ensure the implementation of the human needs while limiting the damages caused to the environment at the same time. Sustainable development has thus become the answer to the maturing need of a new approach to the environmental resources and their use for the needs of men and economy. This approach should include the following features of development, which should include:

- **immaterialisation:** – an increase of a qualitative nature, increasing the share of the immaterial production in the global production (servering the economy – the growing importance of the service sector),
- **dematerialisation** – eco efficiency, separation of the relations between environmental damages and the material production,
- **decarbonisation** – separating relations between the economic growth and the increase in the $CO_2$ production,
- **decoupling** – the separation of the relations between the economic growth and the increase of the transport needs (Tapio et al. 2007, for: Skala-Późniak, 2010).

Prosumer initiatives fit into the implementation of the above-listed economic, environmental and social objectives which the sustainable development should serve. In relation to the economic objectives, prosumption enables: incorporation of the external costs to the prices of fuels and secondary energy, short times of the investment implementation, higher rates of the investment return, potential increase, position and competitive advantage of prosumers of energy, growth of the number of investors, energy producers, reserving in the plans of spatial development the conditions for joining energy prosumers, knowledge exchange and transfer of eco-innovative prosumer technologies, creating new workplaces.

Prosumer actions enable the implementation of the environmental objectives of sustainable development. This is manifested in: the reduction of the lithosphere pollution, hydrosphere, aerosphere, the ability to self-reconstruction of the regional natural environment, regional adjustment in relation to the natural conditions (technical and economic energy potential, environmental capacity) and biological diversity, adjustment of the space of the regional prosumer energy sector including the protected areas (in the EU, e.g., according to the protocol NATURA 2000), determination of the environment absorption and the state of its resources (in the qualitative and quantitative approach), introduction of the reliable, comprehensive assessment of the environment, the skill to manage the protected areas without the harm to the life of their inhabitants. Projects enhancing the prosumer activity also serve the social development, which is also an element of sustainable development. The implementation of this goal, thanks to prosumer initiatives, is expressed in: culture of energy consumption stimulating the growth of ecological awareness, education systems (among others, in the field of ecology, eco innovative energy solutions dedicated to prosumers), improvement of the social welfare and thus the tendency to pay (Cost-Benefit Analysis), increase of the activity of local societies, participation of inhabitants in the public life, stimulation of the economic, financial activity and legislative mechanisms supporting cations for the prosumer energy in the region, creating motivational systems for prosumers of energy, preventing poverty and social exclusion, ensuring the equal access to prosumer technologies, as well as products from the portfolio of the polygeneration energy (Bajor, 2014, p. 7-9).

**The role of the prosumer product for the preservation of the environment**

Much of the studies on prosumption focused on the mere process and essence. However, it is difficult to find closer references to the significant spheres of this activity from the point of view of sustainable development. The widely exposed area of these actions is the use of renewable energy sources for the production of electricity. Here, the attention is paid to the use of photovoltaic sets or fans. Therefore, it is worth reflecting on other fields of prosumer actions, which can be significant for achieving sustainable development. The area of this type can be the construction and modernisation of residential homes, especially single family ones. The owners often join the mere stage of the creation of the new building or its modernisation. This type of activities aim to meet their residential needs, but also the ecological effect should be included in this type of actions, for this type of undertaking and the possibility to reduce or limit the dangers of the thermal installations related to heating of water or rooms for the natural environment. We can thus conclude that the activity related to the construction or modernisation of homes can have the nature of the prosumer actions.

Another sphere of potential prosumer actions important for the condition of the environment is the use of waste from the so-called organic fraction of households and the amount of leaves and mowed grass for the production of compost in order to use it on the household gardens or the potential resale.

Another field of prosumer actions potentially supporting the environment involves the cultivation in the household gardens of vegetables, decorative

plants and used for improving health or fertilisation of the soil. An example of this type of plants includes the nettle, which is a herb and the main element of the natural fertiliser, which has a favourable effect on the plant growth.

Prosumer actions can also involve the use of used euro pallets after construction materials or wood briquettes. They can be used for making garden furniture, and therefore limit the purchase of garden furniture made of plastic, the production of which is harmful to the environment.

The above-mentioned potential spheres of prosumer actions can be treated as the prosumer product used for achieving sustainable development and giving tangible and intangible benefits to people involved in its formation. Intangible benefits resulting from the above-described prosumer product can include the improvement of the health condition of people producing it, resulting from the need of the independent use of the specified physical works, in relation to its formation, what can be an alternative for using a gym, fitness centres and medical advice due to the preventive aspect of the physical activity related to prosumption. The scope of the prosumer product determines the amount of spheres, in which the given person undertook prosumer actions. The involvement of the potential prosumers in them is the effect of three groups of conditions, which include: the necessary expenditures for the specified prosumer undertaking, the scope of knowledge on the given prosumer area and the availability of technologies enabling the implementation of the given prosumer activity. Expenditures in this case include the contribution to work, the necessary time, which you need to have in relation to the given prosumer undertaking and the financial resources for this goal. Another important factor contributing to the formation of the prosumer product is knowledge related to the given sphere of prosumer actions. Sometimes it requires the involvement of the mere potential prosumer into finding the adequate information online or in the literature. In some cases, the role of this type can be fulfilled by the state programs promoting prosumer undertakings from the specified fields. The third important factor determining the formation of the prosumer product is the available technologies, which are used in relation to the specified prosumer undertakings.

From the point of view of caring for the natural environment, is seems reasonable to create conditions for the involvement of people potentially interested in prosumption. Currently, in Poland and in the EU the programs used for developing the prosumer energy sector are developed. It seems that the similar initiatives should be developed in the field of using prosumption in a single- and multi-family construction. This type of programs should be accompanied by the appropriate legislative changes and information campaigns supported by ecological education in the period of education. With regard to the possibility of production of compost or the cultivation of vegetables and plants constituting the base for the natural fertiliser to be used in the household gardens the educational actions should be conducted for this purpose. This role can be performed by the companies providing municipal services, environmental foundations, schools during biology classes. What is also important here is also the own activity of potential prosumers related to searching information on how to independently create this type of eco products. While when it comes to the use of euro pallets after construction materials or other products for producing garden furniture, people interested in this type of actions can find the required information online without too many problems. This type of activity should be supported by programs supporting the online hobby services or offering eco crafts.

## Summary

The phenomenon of prosumption is multidimensional. It is favoured by various conditions, which include the development of technologies enabling the independent production of products and services, which in the earlier phases of economic development could be purchased only on the market principles or on principles determined by the state.

There are several common features of prosumers. These are:

- the need to combine work and family life and the possession of communication tools providing contact with the family and work anywhere in the world,
- the need for ease of use of specific products and services,
  interest in entertainment, on what they are willing to spend more than other consumer groups,
- the willingness to have access to files from home with the same ease as they do it at work, mobility through the use of devices, such as the mobile phone, iPod and laptop,
  intensive use of the Internet and mobile technologies while working at home.

Prosumption as a social activity can be used for the practical implementation of the concept of sustainable development. The common action of political, business decision makers and non-governmental organisation is significant for this purpose. The joint activities of the listed entities decide on the scale and content of the prosumer product described in this study.

## References

1. BAJOR M., 2014, *Zarządzanie energetyką prosumencką w JST – w warunkach zrównoważonego rozwoju*, p. 7-9, http://www.klaster3x20.pl/sites/default/files/bajor_-_zarzadzanie_energetyka_prosumencka _w_jst.pdf (15.05.2016).

2. BAŃKOWSKI T., ŻMIJEWSKI K., 2012, *Analiza możliwości i zasadności wprowadzenia mechanizmów wsparcia gazowych mikroinstalacji kogeneracyjnych – Wsparcie Energetyki Rozproszonej – Energetyka Społeczna*, Instytut E. Kwiatkowskiego, Warsaw, s. 13.
3. BREMDAL B.A., 2011, *Prosumer Oriented Business in the Energy Market,* IMPROSUME Publication Series #2, p. 1-25, http://www.ncsmart .com/wp-content/uploads/2014/01/Prosumer-oriented-business-in-the-energy-market-finale.pdf (21.05.2016).
4. BRUNS A., 2008, *Blogs, Wikipedia, Second Life, and beyond. From production to produsage*, Peter Lang, New York, p. 21
5. BYWALEC C., RUDNICKI L., 2002, Konsumpcja, PWE, Warsaw, p. 130.
6. GIBBERT M., LEIBOLD M., & PROBST G., 2002, Five Styles of Customer Knowledge Management, and How Smart Companies Use Them To Create Value, in: *European Management Journal* 20 (5), p. 459-469 (20.05.2016).
7. GILMORE J. H., & PINE B. J., 1996, The four faces of mass customization, in: *Harvard Business Review*, 75(1), p. 91-101.
8. HEILBRUNN B. (red.), 2000, *Zachowania konsumenta. Koncepcje i badania europejskie* PWN, Warszawa.
9. KOTLER P., 1986, The prosumer movement: a new challenge for marketers, in: *Advances in Consumer Research* 13, p. 510-513.
10. LEBIEJKO A., 2001, Prosumer – a new trend of active consumption on the example banking services, in: *Journal of Interdisciplinary Research*, no. 1 (2)., p. 65.
11. MAZUR O., & ARCHAKOVA K., 2011, *Customer driven innovation,* http://www.diva-portal.org/smash/record.jsf?pid=diva2%3A420852&dswid= topdog (25.05.2016).
12. MICHAEL S., 1997, *Prosuming-Marketing. Konnzeption und Anwendung*, Verlag Paul Haupt, Bern, Stuttgard, Wien.
13. MACHOWSKI J. , Ochrona środowiska. Prawo i zrównoważony rozwój, Żak, Warsaw 2003, p. 100-101.
14. MAJOBUB W., 2014, Co-creation of Value or co-creation of Experience? Interrogations in the field of Cultural Tourism, in: *International Journal of Safety and Security in Tourism*, no. 7. p. 12-31.
15. PIHL Ch., WAHHLQVIST E., 2008, *Consumer-driven prosumption: The case of Swedish fashion bloggers and the emergence of new value networks*, University of Gothenburg, School of Business, http://www.reser.net/materiali/priloge/slo/pihl_c_wahlqvist_e.pdf (24.05.2016).
16. PIONTEK B., 2002, *Koncepcja rozwoju zrównoważonego i trwałego Polski*, PWN, Warsaw, p. 51.
17. PRAHALAD C.K., & RAMASWAMY V., 2004, Co-creation experiences: The next practice in value creation, in: *Journal of Interactive Marketing*, 18(3), p. 5-14, http://doi.org/10.1002/dir.20015 ( 22.05.2016).
18. *Przez zrównoważoną konsumpcję do zrównoważonego rozwoju*, dokument Ministerstwa Gospodarki, 2012, http://www.mg.gov.pl/files/upload/10902/Broszura%20konsumpcja.pdf (22.05.2016).
19. *Polska Energetyka na Fali Megatrendów*, 2016, http://www.econet-poland.pl/fileadmin/ahahk_polen_econet/Publikationen/FAE_Polska_energetyka_na_fali_megatrendow_Styczen_2016.pdf (23.05.2016).
20. RITZER G., DEAN P., JURGENSON N., 2012, The Coming of Age of the Prosumer, in: *American Behavioral Scientist*, April 1, p. 379-398.
21. RODRIGUEZ-MOLINA J.M., MARTINEZ-NUNEZ J., PEREZ-AGUIAR W., 2014, Business Models in the Smart Grid: Challenges, Opportunities and Proposals for Prosumer Profitability, smart grid; business model; prosumer, in: *Energies* 7, p. 21, p. 6142-6171, http://www.mdpi.com/journal/energies (24.05.2016).
22. SKALA-PÓŹNIAK A., 2010, *Zjawisko decouplingu w gospodarce w okresie transformacji*, Prace Naukowe Politechniki Warszawskiej, Transport 72, p. 101-113.
23. *State of the environment report No 1/2007*, European Environment Agency, 2007, http:www.eea.europa.eu/pl/publications/srodowisko-europy-2014-czwarty-raport-oceny (22.05.2016).
24. TOFFLER A., 1980, *The Third Wave*, Collins, London.
25. TOLINO A., 2010, *Gaming 2.0 – Computerspile und Kulturproduktion, Analyse der Partizipation*, p. 339-369.
26. Van RAAIJ F., 2001, Konsumpcja postmodernistyczna, in: M. Lambkin, G. Foxal, R. van Raaij (eds.), Zachowanie konsumenta, koncepcje i badania europejskie, PWN, Warsaw, p. 332.

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# A Three-dimensional Aproach in Education for Sustainable Future

# Trójwymiarowe podejście do edukacji dla zrównoważonej przyszłości

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## Abstract

The concept of sustainable development is used in a growing number of new contexts (ever-modernising technologies, developing science, environmental protection, politics) and levels (global, regional, national, institutional, personal). The concept differs depending on an area in which it is used. Business, technologies and politics use typical, already existing approaches to sustainable development. The projection/transposition of sustainable development paradigm into the sphere of education, science, technologies, economy, environmental protection and politics acquire the specifics of a sphere, namely structure and terminology, and has different elements. A wide field of human activity and different levels of the implementation of the concept of sustainable development make the analysis of this development and its implementation in the education sector more difficult. Both scientific and practical educational discourse need common parameters, common dimensions which unify the different areas of sustainable development and allow educators to accurately convey a full picture of this development. In this article, we will highlight educational approach towards a sustainability paradigm by analysing the common dimensions of sustainable development. We will talk about the levels of the implementation of sustainable development by concentrating on education at a personal level. Having applied the triangle of the dimensions of sustainable development (Place, Permanence, Persons), created by L. Seghezzo, to explain and analyse the concept of quality of life, in the article, we will present a three dimensional model of education for sustainable development.

**Key words:** sustainability, sustainable development, quality of life, education

## Streszczenie

Termin rozwój zrównoważony jest używany w coraz większej ilości nowych kontekstów (technologicznym, rozwoju nauki, ochrony środowiska, polityki) i na różnych poziomach (globalnym, regionalnym, krajowym, instytucjonalnym, indywidualnym). Konsekwentnie będzie on także różnorodnie interpretowany. W świecie biznesu, techniki i polityki wykorzystywane jest tradycyjne, już istniejące podejście. Projekcja/transpozycja paradygmatu zrównoważonego rozwoju w sferę edukacji, nauki, techniki, ekonomii, ochrony środowiska i polityki wymaga określenia struktury i terminologii, składających się z różnych elementów. Różnorodność ludzkich działań na różnych poziomach wdrażania koncepcji zrównoważonego rozwoju powodują, że badanie tego rozwoju i jego impelmentacja w sektorze edukacyjnym to trudne zadanie. Dyskurs edukacyjny, zarówno naukowy jak i praktyczny, wymaga pewnych wspólnych parametrów i odniesień, które ujednolicają różne konteksty zrównoważoności i pozwalają edukatorom trafnie przekazać wielowymiarowość tego rozwoju. W tej pracy skoncentrowano się na edukacyjnym podejściu do paradygmatu zrównoważonego rozwoju poprzez analizę jego składowych. Przedstawione zostaną poziomy implementacji rozwoju zrównoważonego w odniesieniu do

edukacji na poziomie indywidualnym. Dzięki odwołaniu do wprowadzonego przez L. Seghezz'ego trójwymiarowego podejścia do wymiarów rozwoju zrównoważonego (Miejsce, Trwałość, Ludzie) możliwa będzie analiza i wyjaśnienie koncepcji jakości życia, co prowadzić będzie do prezentacji trójwymiarowego modelu edukacji dla zrównoważonego rozwoju.

**Słowa kluczowe:** zrównoważoność, rozwój zrównoważony, jakość życia, edukacja

## Introduction

Contemporary society, which is innovation-oriented, provides a capability for the rapid commercially successful prosperity growth of innovation right holders as never before. We are living during the period when a major part of production is being replaced by robots, when human creativity is the most desirable competence. This is a time when the creative class is emerging (Florida, 2002). An essential precondition for prosperity growth is creative skills that are arising not so much from inspiration as from the analysis and experiments. This confers an advantage to those society groups, regions and countries which are more educated and have better possibilities for the introduction of innovations. This creates a closed circle – better conditions result in innovations, innovations result in the prosperity of the ones that made them. In order to avoid the widening of the gap and to encourage its reduction, it is attempted to ensure the sustainable development of a country and the whole world by laws, regulations and recommendations. The concept of sustainable development covers a constantly widening social and thematic field. The contexts (ever-modernising technologies, developing science, environmental protection, politics) and levels (global, regional, national, institutional, personal), which are covered by it, are widening. The development of the concept of sustainable development is becoming a significant challenge for education: how to effectively convey to the younger generation the comprehensiveness of sustainable development at the levels of knowledge, attitudes, values, skills and behaviour. A sustainable development paradigm provides a new approach towards environmental protection and quality of life, therefore, there is a need to find ways of preparing the younger generation, while educating it, for sustainable decisions and harmonious future. During the 20th century the connections between the prosperity of the society and its continuous social hierarchy, in which there are no significant gaps, were observed. The continuity of social hierarchy (or the absence of gaps between social positions) is reflected in societal indicators and indexes. In educology, education for sustainability is often linked to ecology. Although scientific discourse even tells about innovation ecology (Adkins et al., 2007), industrial ecology (Cohen-Rosenthal, 2004), media ecology (Cottle, 2004), creative industries ecology (Kačerauskas, 2016). However, such diversity of the usage of ecology cannot fully reflect the content of sustainable development which has to be conveyed to the younger generation when educating it. It is necessary to define the multidimensionality of sustainable development in educology very accurately, as it covers a very broad field of the development of the society and all human activities (global, regional, local) (Pawlowski, 2008).

In this article, when analysing the common dimensions of sustainable development, we will highlight the educological approach towards a sustainable development paradigm, we will talk about the levels of the implementation of sustainable development, while concentrating on education for sustainable development at a personal level.

The purpose of this article is to present a three-dimensional model of education for sustainable development by revealing the dimensions of sustainable development from time, place and personal perspectives.

The article was inspired by D. Springett's (2016) editorial *Education and the Problems of Sustainable Development* encouraging to engage a wider audience in the discourse of sustainable development, to examine the role of education when preparing young people for sustainable development of the society. In response to the question raised by the author *What is education for?*, this article agrees with the claim of the author and confirms it that young people should be *educated to aspire to a transformational role as agents of change and to envision the moral economy of social justice, citizenship and sustainability, based in social democracy* (Springett, 2016).

## Sustainable development at different levels of implementation

The implementation of a sustainable development paradigm covers different levels of societal life by networking, for the common goal, all the politicians, scientists, producers and creators.

A. Pawłowski (2011) draws attention to the fact that, in the concept of sustainable development, seven dimensions can be distinguished: ethical, ecological, social, economic, technical, legal and political. The author classifies the dimensions into three levels, the first level is ethical dimension, the second one is ecological, social and economical dimensions and the third one is technical, legal and political dimensions. All the dimensions are equally important (Pawlowski, 2011). When examining a sustainable development paradigm through the vertical prism of the implementation policy five

levels can be singled out. The first level, at which problems are raised and their strategic implementation is envisioned, is global, starting with the UN *Agenda 21* (1992), which was formulated at the beginning of the 1990s, the objectives of sustainable development are regularly formulated up until last *Sustainable development goals* (2015). The second one is a regional level covered by *EU Sustainable Development Strategy* (2015) and other documents regulating the implementation of international agreements). The third one directs sustainable development procedures at national level. In Lithuania's case, there is the *Lithuanian National Strategy for Sustainable Development* (2003), *National Progress Strategy 'Lithuania 2030'* (2011), the *National Progress Programme for Lithuania for the period of 2014-2020* (2012). The fourth one is a local level: the *Agenda 21* in the municipality, company and school. And the last, but not the least – a personal level: the lifestyle of the individual, his behaviour in relation to others, encompassing a specific type of behaviour in relation to his environment and surrounding people and the abstract one directed at general well-being and the well-being of future generations.

Education of personality is always based on values, attitudes and skills that are sustainability competencies. There is no universal definition of sustainability competencies, however, P. Pace (2010) identified three areas of competences for sustainable development: cognitive competence of sustainable development, action (behaviour) competence, and social and civil competence. These competences find their expression at a personal level, therefore, as far as education for sustainable development is concerned, the level of personal implementation is the most important. As far as education of personality in the context of sustainable development is concerned, the concept *sustainability thinking* is used (Pace, 2010). This notion characterise very well the sought-after competence for sustainable development, although in different contexts – scientific, technological, environmental, societal, economic and policy/political – this concept is used differently (Zoller, 2015).

The commonly accepted concept of sustainable development is a definition of the World Commission on Environment and Development (WCED), which describes *sustainable development* as a development that meets the needs of the present without compromising the ability of future generations to meet their own needs (Brundtland Report, 1987). The European Commission has formulated an external strategy to ensure that, by working in partnership with other countries, it can drive forward global aims based firmly on three fundamental pillars: economic, social and environmental responsibility. The European Commission has also introduced a sustainable development *triangle* formed by *People, Planet and Prosperity*, which is commonly used in business and governments (The World Summit on Sustainable Development, 2002). In 2009 L. Seghezzo proposed the concept which complemented the WCED defined *sustainable development* concept of three dimensions (Seghezzo, 2009). L. Seghezzo suggested *a better understanding of the sustainability by using a triangle formed by 'Place', 'Permanence', and 'Persons'. Here Place is the three-dimensional physical and geographical, but also culturally constructed space where we live and interact; Permanence – the potential long-term effects of our actions or in another words – time; and Persons – the fifth dimension, a symbol of people as individual human beings and not as undifferentiated members of society* (Seghezzo, 2009). These dimensions – Place, Permanence, Persons – are particularly important as far as sustainable development in the context of education is concerned. These dimensions allow to shift the ideas of sustainability into personal level which is, after all, the ultimate goal of (self-)education and the ultimate goal of the strategy for sustainable development. The personal level determines how the goal of sustainable development will be implemented, what personal and group decisions will be made, what quality of life individually and collectively will be. We decide what better living at a personal level means to us, it is as if we look for the answer to the fundamental question asked by E. Fromm: *To have or to be?* (Fromm, 1976).

As far as a personal implementation of the strategy for sustainable development level in the context of education is concerned, it is important to mention that a person's lifestyle, his culture of consumption depend on a person's concept of quality of life. In order to analyse and evaluate the concept of quality of life, we employ L. Seghezzo's triangle of dimensions of sustainable development *Place, Permanence, Persons* and we present it in the context of the education for sustainable development.

## The concept of quality of life based on the dimensions of sustainable development *Place, Permanence, Persons*

The concept of quality of life was changing from Aristotle's (384-322 BC) concept of *eudaimonia*, when individuals were called on to realize their full potentialities in order to achieve a *good life*, to a modern approach which is officially presented by the World Health Organisation which describes quality of life as *the individual's perception of his place in life which depends on the culture in which an individual lives, his value system, goals, hopes, norms and interests. It is the concept describing a multiple-component phenomenon, encompassing* personal physical health, psychological well-being, *the level of independence, social relationships, personal convictions and environment* (Study Protocol for the World Health Organization Project to

Develop a Quality of Life Assessment Instrument (WHOQOL), 1993).

In scientific discourse, there exists a number of the concepts of quality of life (Diener and Suh, 1997; Hughes, 2006), however, in the context of education for sustainable development the philosophy of Immanuel Kant, who invited to build a good society by acting morally and never linked morality to happiness, is the most relevant. Happiness, according to him, is very individual and, consequently, volatile, whereas morality has to be the same for all. The factor of moral action is a duty which leads the man to behave based on mind, rather than on the basis of own vagaries or happiness. This perspective is alien to today's hedonistic society, however, when rethinking quality of life through the prism of sustainable development this is the approach which must be encouraged.

In order to transfer the concept of quality of life into personal level, that is to assist an individual to understand quality of life, we suggest examining it on the basis of L. Seghezzo's paradigm Place – Permanence – Persons, that is to look at quality of life from three perspectives – place, time and personal. The paradigm suggested by L. Seghezzo (2009) consists of five dimensions. The first part of the triangle, i.e. *Place*, consists of three dimensions: these are the culture of countries, their lifestyle, people's physical and mental health. *Permanence* denotes not only the existing situation, but also changes and improvements that is a perspective. Permanence could be seen as the main realm of inter-generational equity. *Persons* – personal approach, philosophy (Seghezzo, 2009). The personal commitment may play a distinctive role in the pursuit of better intergenerational justice since humans have the freedom to be relatively autonomous from both their environment and their culture, as postulated by A. Maslow (1954).

Let us examine how, at a personal level, the concept of quality of life and own commitment to quality of life change, based on L. Seghezzo's triangle of sustainable development Place – Permanence – Persons (Seghezzo, 2009). We will single out three levels of the concept of the individual that are important to education. The analysis of possibilities of internalisation of sustainability attitudes in educational system may be elucidated using the model of cognitive development. Levels in cognitive development have *invariant sequence* (Kohlberg, 1984). Lower levels ground the higher ones; changes between levels are structural transformations rather than accumulation of knowledge and experience – higher stages integrate or displace lower ones (Kohlberg, 1984). Cognitive development and behaviour changes mutually influence one another. Neither cognitive development without behavioural interactions nor behavioural interactions without cognitive development may result moral development in L. Kohlberg's theory, which is a close to presustainability paradigm theory, described similarly to contemporary sustainability issue. The development may be educated both in school and in family. While performance of the role of family in education depends on the values of parents, school programmes contain the issues as integrated as well as separate subject of civil education.

The first level of the concept of quality of life, which reflects the simplest concept, is *Here – Now – I*. This concept is based on taking care of self in a present time. This is a hedonistic concept, which is characterised by ephemeral living, inability to link the consequences of own behaviour with quality of life. The representatives of this concept do not think about influence of their own behaviour and lifestyle on the environment. The approach of this individual is the basis for selfish attitudes to which the whole attention of the educator must focused. As a rule, such person does not think that he himself, his conscious or unconscious behaviour may have influence on people around or himself in the future. This level is similar to preconventional (or premoral) level in the theory of moral development of L. Kohlberg (1984). The attitude towards others inherent for the level – individualistic hedonism (Kohlberg, 1984), the interaction with others at the level forms awareness of the interests of other people. Although it is difficult to position transition from one level to another in lifetime very precisely, all L. Kohlberg researches relate transition to conventional level in primary school. The transition to a higher level is supported through the subjects of moral development as well as integrated to almost all school subjects. In addition to acquaintance of knowledge, circumstances that allow practical activities in authorities-free space are essential for the primary school children. Bilateral non-hierarchical interactions help to construct understanding about interaction roles models, empathy and rules that construct behavioural expectations. The institution of a form prefect empowers pupils for an equal relationship and the coordination of interests (or rather wishes at this level).

The second level of the concept of quality of life is *Neighbourhood – Tomorrow – Relatives*. For the proponent of this concept, both his own quality of life and that of the people in his immediate environment are important. He understands the consequences of his own behaviour and the behaviour of the people of his immediate environment which will have effect on them in the nearest future. A person may also see a possibility to influence the life of the people of his immediate environment or his own not only in the present, but also after a few years. This individual is concerned how orderly, prosperously his neighbours live, however, this concern is only for the sake of convenience. When analysing quality of life, this proponent of the concept understands the aspects which determine quality of life of his and the people of his immediate

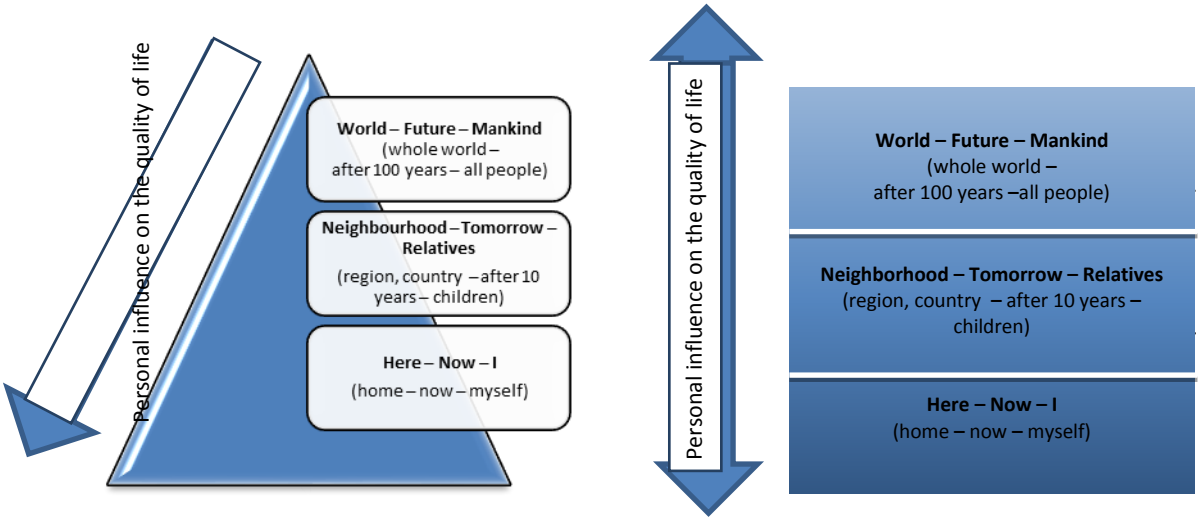
environment. He realises that his quality of life depends on the culture of consumption, lifestyle, values of the people living in his neighbourhood. When thinking on quality of life and sustainability the individual is able to encompass a decade in his thoughts. The level is similar to Conventional morality level in L. Kohlberg's theory of moral development (Kohlberg, 1984). At this level, the individual is *aware of shared feelings, agreements, and expectations that take primacy over individual interest* (Kohlberg, 1984). At this level, there is belief in the Golden Rule and behaviour based on expectations of others, recognition of society as institution that functions for protection and welfare of its members (Kohlberg, 1984). However, the level is insufficient for the implementation of the paradigm for sustainable development. Insufficient due to lack of critical attitude towards contradicting aspects of society and focus on support of positive aspects of society thus keeping *Status Quo*. That usually does not lead to attitude that supports change of society towards sustainability. Although different measurements show different ages of transition from one period to another, conventional level is generally typical for lower secondary school. Civil education at lower secondary is an integrated subject. Responsibility and values are subjects for education within almost all school subjects. While school subjects stimulate cognitive development, interactions within the same position remain an in-group interaction. The level usually starts to have school parliaments that enforce the development of responsibility, trust in own actions and belief in change possibilities.

For sustainable development of society, it is necessary that each person would clearly realise how, both tomorrow and after many years, the quality of life of future generations will depend on his personal behaviour and that of certain population groups (which are brought together by geographical situation) behaviour. The younger generation must realise how the lifestyle, the culture of consumption of the people living on the other side of the planet has an effect on us now, what consequences it will have in the long term. It is the third level. In order to do that, it is necessary that the educatees would interact with the groups, which are outside their educational institution, especially with two types of theirs – vulnerable, the change of the condition of which could become an objective, and socially active ones, the belief of which in their own powers may become an example. The preconditions created by the previous level – the positive assessment of society and human nature – make it possible for such change to occur. In this period of the educatee's development, the educator should develop conditions for an active outer interaction. Each individual's quality of life depends on quality of life in the district, country, region and even the world. How much environment, in which we live, is polluted, what products we feed on depends on what the culture of consumption in the region is. Our present life depends on how our ancestors lived. It is important to instill knowledge-based and understanding-based responsibility for their actions in young people. However, this cannot be achieved without a place, time and individual perspective. In this sense, sustainability is three-dimensional. And bearing in mind the tridimensionality of the L. Seghezzo's (2009) *place* element and including into the concept of place not only geographical, but cultural and health dimensions also, education for sustainable development becomes five-dimensional, that is encompasses five dimensions. As is argued by J. Hucle (2012), it is necessary that educatee would be acquainted with the forms of environmental, ecological and global citizenship that give expression to the Earth Charter principles and our responsibilities to other species and people at a distance in space and time (Hucle, 2012).

Accordingly, the more the individual, when evaluating quality of life, is able to move away from the concept *Here – Now – I*, the more he is approaching the sought-after concept of sustainable development in the context of *World – Future – Mankind*. The more the person realises his own influence, understands the extent of his behaviour with respect to time, place and other people, the better sustainability competence he has. This relates to a sense of responsibility which increases with the increase of belief in their own possibilities to influence the surrounding world, to influence changes. Similar to Postconventional, or principled, level of L. Kohlberg's theory of moral development (Kohlberg, 1984) it sees ethical principles as prior-to-society. The attitude allows sustainability as a process as well as a goal. L. Kohlberg describes the attitude of the level: When laws violate… principles, one acts in accordance with the principle (Kohlberg, 1984). This approach may arise in educatees in the final years of school of general education and the segments of higher education. The person on the level of development chooses the principled action knowing that individual goals of part of society will oppose, or at least doubt his choice. At this level, civil education is thought both as a separate and as an integrated subject. In order to encourage it, the educator must create opportunities that his educatee would engage in the reflection of his own activity and personality, encompassing the analysis of future projections.

The application of *Place – Permanence – Persons* paradigm in education for sustainable development is shown in Figure 1.

The application of L. Seghezzo's (2009) *Place – Permanence – Persons* model in educology enables to convey to educatees a general context of sustainable development and to form an appropriate concept of quality of life.




1. Personal influence on the quality of life: common situation
2. Personal influence on the quality of life: desired situation

Figure 1. The application of a *Place* – *Permanence* - *Persons* paradigm in education for sustainable development

## Conclusions

Sustainable development is impossible if it remains only at political – international and national – levels. The implementation of policy documents is impossible without the personal attitudes of the members of society with respect to sustainability, because personal attitudes determine actions giving rise to sustainable development, whereas policy documents and rights encourage more often the acting one to formally comply. Because of that, it is necessary to form the attitudes of sustainability when educating the members of society. In order to implement a sustainable development paradigm at a personal educatee‘s level, it is important to take into consideration not only the areas of sustainable development, but also the levels of its implementation. It is important to ensure an educatee‘s concept of quality of life corresponding to sustainable development, which encompasses the perspectives of place, time and personal approach, which are characteristic of different age periods of educatees. Due to integral development encompassing parallel cognitive and behavioural evolution, it is impossible to segment the education of sustainable development only into cognition or only into the action. Therefore, it is impossible to explain sustainable development by employing one, e.g., personal or time, perspective. Despite such dimension of sustainability, in scientific discourse, integrated approach to education for sustainable development is often developed, sustainable development is presented as a whole. The essence of sustainable development is continuous evolution, therefore, only systemic and overall application of the paradigm or principle is possible – in every area, at every level of the governance of society. Sustainable development will always be related to human values, human attitude towards environment, surrounding people and their future, his level of responsibility and actions. Both conveying the content of sustainable development and assessing the depth of the educatee‘s understanding, the dimension of the concept of quality of life and the level of responsibility are among fundamental things. The goal is to involve educatees in thinking through both personal and broader societal issues and to hold a mirror to the world and show it as it is and as it has produced and shaped its own nature. That is what O’Connor (1998, p. 52) invited to do.

## References

1. ADKINS B., FOTH M., SUMMERVILLE J., HIGGS P., 2007, Ecologies of innovation – Symbolic aspects of cross-organizational linkages in the design sector in an Australian inner-city area, in: *American Behavioral Scientist*, vol. 50, no 7, p. 922-934.
2. COHEN-ROSENTHAL E., 2004, Making sense out of industrial ecology: a framework for analysis and action, in: *Journal of Cleaner Production*, vol. 12, no 8-10, p. 1111-1123.
3. COTTLE S., 2004, Producing nature(s): on the changing production ecology of natural history TV, in: *Media Culture & Society*, vol. 26, no 1, p. 81-101.
4. *Darnaus vystymosi darbotvarkė iki 2030 metų, 2015*, https://sustainabledevelopment.un.org/post2015/transformingourworld (22.06.2016).
5. DIENER E., SUH E., 1997, Measuring quality of life: economic, social and subjective indicators, in: *Social Indicators Research*, vol. 40, p. 189-216.

6. FLORIDA R., 2002, *The Rise of Creative Class. And how it's transforming work, leisure, communitiy and everyday life*, Basic, New York.
7. FROMM E., 1976, *To Have or to Be? The nature of the psyche*, Harper & Row, New York
8. HUCLE J., 2012, Towards a greater realism in learning for sustainability, in: *Learning for Sustainability*, p. 35-48, http://john.huckle.org.uk/download/2958/LfSChapterOne2012.pdf (10.07.2016).
9. HUGHES M., 2006, Affect, Meaning and Quality of Life, in: *Social Forces*, vol. 85, no. 2, p. 611-629.
10. KAČERAUSKAS T., 2016, Discourses of Ecology and the Sketches of Creative Ecology in the Context of Sustainable Development, in: *Problemy Ekorozwoju/ Problems of Sustainable Development*, vol.11, no.1, p. 31-39.
11. KOHLBERG L., 1984, *The Psychology of Moral Development. Nature and Validity of Moral Stages*, Harper and Row, San Francisco.
12. MASLAW A.H., 1954. *Motivation and personality*, Harper & Bros., New York, in: Seghezzo, 2009.
13. O'CONNOR J., 1998, *Natural Causes. Essays in Ecological Marxism*, Guilford, New York.
14. PACE P., 2010, *E*ducation for sustainable development: current fad or renewed commitment to action*?* In: *Journal of Baltic Science Education*, vol. 9, no. 4, p. 315-323.
15. PAWŁOWSKI A., 2009, How many dimensions does sustainable development have?, in: *Sustainable Development*, vol. 16 no 2, p. 81-90.
16. PAWŁOWSKI A., 2011, *Sustainable Development as a Civilizational Revolution. Multidimensional Approach to the Challenges of the 21st century*, CRC Press, Taylor & Francis Group, A Balkema Book, Boca Raton, Londyn, Nowy Jork, Leiden.
17. SEGHEZZO L., 2009, The five dimensions of sustainability, in: *Enironmental Politics*, vol.18, no. 4, p. 539-556.
18. SPRINGETT D., 2016, Education and the Problems of Sustainable Development, in: *Problemy Ekorozwoju/ Problems of Sustainable Development*, vol. 11, no 1, p. 7-14.
19. Study Protocol for the World Health Organization Project to Develop a Quality of Life Assessment Instrument (WHOQOL) (1993). *Quality of Life Research*, vol. 2, no. 2, p. 153-159, http://www.jstor.org/stable/4034396 (21.08.2016).
20. *The World Summit on Sustainable Development. People, planet, prosperity*, 2002, http://ec.europa.eu/environment/archives/wssd/documents/wssd_brochure.pdf (21.08.2016).
21. WCED (World Commission on Environment and Development), 1987, *Our Common Future*, Oxford University Press, New York.
22. ZOLLER U., 2015, Research-Based Transformative Science/ STEM/ STES/ STESEP Education for Sustainability Thinking. From: Teaching to 'Know' to Learning to 'Think', in: *Sustainability*, vol 7, no. 4, p. 4474-4491.

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# Sustainable Development of a City: Systemic Approach

# Rozwój zrównoważony miasta: Podejście systemowe

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## Abstract

Today the concept of sustainable development has been adopted as a basis for promoting development at all levels of territorial organisation. While generally worked out for the global level, this conception has also attained a local dimension, after the local *Agenda 21* had been drawn up at the Rio conference in 1992. However, each level of development planning has its own specific features, and so have individual territorial units at that level. This also, or perhaps primarily, concerns cities because of wide differences in their sizes, the complexity of relations occurring there, the accumulation of development problems, the special role they play in the settlement system and difficulties with transferring the assumptions of a conception worked out for the global scale to the local level. This paper seeks to find a way of understanding sustainable development appropriate to the specificity of a city, with special attention paid to a systemic conception, and more specifically that of a territorial social system. Also, an analysis is made of selected conceptions and models indicating concrete measures that should be taken to make urban development more balanced, especially in its spatial aspect. The reflections lead to the conclusion that sustainable urban development can hardly be associated with the sustainability presented in the report *Our Common Future*; rather, it should involve a search for conditions of a city's intra- and inter-system balance and relations with its immediate and farther vicinity.

**Key words:** city, urban system, sustainable development, territorial social system, sustainable development model and conceptions

## Streszczenie

Koncepcja zrównoważonego rozwoju przyjmowana jest współcześnie jako podstawa wszelkich działań na wszystkich poziomach organizacji terytorialnej. Choć generalnie wypracowana została dla skali globalnej, po przyjęciu na konferencji w Rio w 1992 roku programu *Agenda 21* uzyskała dodatkowo wymiar lokalny. Jednakże, każdy poziom planowania rozwoju ma swoją specyfikę, podobnie zresztą jak poszczególne jednostki terytorialne w ramach tego samego szczebla. Specyfiką taką charakteryzują się także miasta, w szczególności miasta duże, w odniesieniu do których, ze względu na złożoność występujących relacji, nagromadzenie problemów rozwojowych oraz ponadlokalną rolę, jaką pełnią te jednostki w systemie osadniczym, rozwój zrównoważony musi być rozumiany nieco inaczej, niż ma to miejsce w przypadku jednostek terytorialnych wyższego szczebla. Celem niniejszego artykułu jest wskazanie na sposób pojmowania rozwoju zrównoważonego, który odpowiadać będzie specyfice miasta, traktowanego jako system, a konkretnie jako terytorialny system społeczny. Dokonany też zostanie przegląd wybranych koncepcji i modeli wskazujących na konkretne działania, które należy podjąć, aby rozwój obszarów miejskich uczynić bardziej zrównoważonym, zwłaszcza w aspekcie przestrzennym. Przeprowadzone w artykule rozważania prowadzą do wniosku, że zrównoważony rozwój obszarów miejskich trudno jest wiązać z koncepcją podtrzymywalności, na której opiera się raport Nasza Wspólna Przyszłość, ale raczej powinien być

rozumiany jako poszukiwanie warunków równowagi w systemie miasta. Chodzi zarówno o równowagę wewnątrz, jak i między-systemową oraz o kształtowanie właściwych relacji z bliższym i dalszym otoczeniem miasta

**Słowa kluczowe:** miasto, system miasta, rozwój zrównoważony, terytorialny system społeczny, modele i koncepcje rozwoju zrównoważonego

## 1. Introduction

Since the popularisation of the concept of sustainable development, this kind of development has been adopted at various levels of territorial organisation, also that of a city, as a basis for all measures taken. A special role is assigned to measures adopted at the local level, since this rung of organisation is thought to be best suited for the implementation of the principle of sustainable development. The problem is that communes tend to vary greatly, even within a single country: the situation of a small rural commune is certainly different from that of a town, especially a large city – the core of an agglomeration or a metropolitan centre. The multiplicity of development factors and determinants in communes and problems they have to face forces them to adopt various sustainable development policies. Cities, in particular large ones, stand apart here, performing a special role of high-ranking central places in a settlement system and characterised by highly complicated systems of functional links, both internal and external, i.e. with the nearest and farther suburban zones with which they make up a functional region. It is because of this uniqueness that their sustainable development programmes cannot accommodate only the basic goals, or pillars, of this type of development described in the report *Our Common Future* and largely assuming a high level of self-reliance of the spatial units concerned; they must also reflect problems specific to a city and the complexity of functional links occurring there (Mierzejewska, 2015).

This paper seeks to find a way of understanding sustainable development appropriate to the specificity of a city, with special attention paid to a systemic conception, and more specifically that of a territorial social system. Also, an analysis is made of selected conceptions and models indicating concrete measures that should be taken to make urban development more balanced, especially in its spatial aspect.

## 2. Understanding sustainable development

Sustainable development as an idea or conception was made popular in 1987 by the report *Our Common Future*, where it was defined rather laconically as *the development that meets the needs of the present without compromising the ability of future generations to meet their own needs* (WCED, 1987). As follows from this definition and the report as a whole, this type of development rests on a few basic notions (pillars), namely: (1) needs and the necessity to satisfy them, (2) an intra- and inter-generational type of social justice, and (3) limitations imposed on the economy by the natural environment. Thus, it should involve deliberate building of proper relations between economic growth, care for the environment (first of all natural), and the satisfaction of various human needs that significantly determine the quality of life (Koglin, 2009; Petrişor, Petrişor, 2013). It is not supposed to be a deterrent to economic development, but to be a new approach to it, opposing the traditional understanding of economic development while still maintaining a high level of wealth (Domański, 2006). There is no doubt, therefore, that such development has to be well-thought-out and planned, although one should be aware of problems involved in the operationalisation of this conception, also at various rungs of territorial organisation (Mierzejewska, 2009).

Even this general approach to sustainable development can raise some doubts as to how the concepts of needs and social justice should be understood with reference to a city, and in particular, how to accommodate limitations imposed on its economy by the natural environment (Table 1). After all, a city satisfies not only the needs of a local community, but also of residents of its suburban zone, while requiring a steady, everyday supply of matter and energy (in particular food), hence it heavily depends on this very zone for it. In turn, the level of the economic development of cities performing the role of growth drivers in the age of globalisation greatly exceeds their ecological capacity as determined by the quantity and quality of their natural resources, thus making it necessary for them to rely on the ecological capacity of their suburban zones. It seems, therefore, that it is impossible to fully accommodate limitations that the natural environment imposes on the economic development of a city, and hence to apply the conception of sustainable development formulated in *Our Common Future* to it (Mierzejewska, 2015).

Thus, the city requires a different approach to the issue of sustainable development, for example a generally accepted integrated approach embracing its social, economic and ecological aspects, and often also spatial and institutional ones. Such an approach is presented by a variety of authors, including Norgaard (1989), Sneddon, Howarth and Norgaard (2006), Bugge and Watters (2003), Mierzejewska (2009), Koglin (2009), Jenks (2010), Petrişor and Petrişor (2013), and others. This understanding of sustainable development means that none of the fields of human activity (social, economic and ecological) will develop at the cost of the other ones (Borys, 1999). However, one should be aware that it

Table 1. Problems with the operationalisation of the conception of sustainable development presented in *Our Common Future* with reference to a city (Mierzejewska, 2015)

| Sustainable development pillars | Problems |
|---|---|
| concept of *needs* | - no elucidation of what concrete needs are meant<br>- structure and hierarchy of needs of residents of individual cities differ considerably |
| social justice<br>(intra- and inter-generational) | - can be treated as a synonym of distributive justice giving rise to much controversy, disputes and emotions, referring to division of highly appreciated goods in society (Hayek, 1993; Szewczak, 2011)<br>- division of goods is one of basic functions of policy, but it is hard to determine when this division can be regarded as just |
| concept of limitations | - based on conceptions of carrying capacity, environmental space and ecological footprint allowing economy to be run within limitations imposed by the quantity and quality of environmental resources, which is very hard to determine<br>- economic development of a city (especially a large one) is impossible within limits imposed by its natural environment (in order to develop, the city has to rely on the ecological capacity of its immediate and farther hinterland) |

Table 2. Model of relations holding in an urban system, own compilation on the basis of Chojnicki (1989)

| Aspects | | Human community | Territory | |
|---|---|---|---|---|
| | | | natural environment (nature) | artificial elements (economy) |
| Human community | | $x_{11}$ | $x_{12}$ | $x_{13}$ |
| Territory | natural environment (nature) | $x_{21}$ | $x_{22}$ | $x_{23}$ |
| | artificial elements (economy) | $x_{31}$ | $x_{32}$ | $x_{33}$ |

is very hard to meet this condition because practically every human activity produces smaller or greater changes in the natural environment. It is therefore assumed that when one of the spheres has suffered as a result of development processes, suitable compensatory measures should be taken. On this understanding, this type of urban development is identified not so much with the sustainability discussed in *Our Common Future*, but rather with certain relations, a balance, between the individual aspects or spheres of development (social, economic, ecological), closely associated with a city's spatial form (Jenks, 2010). However, it also follows from this approach that such development will not appear of itself; it has to be planned and implemented by all entities active in a city (local authorities, residents, economic entities, non-governmental organisations, associations, etc.). In its planning, in turn, it is advisable to adopt a systems conception of a city (Mierzejewska, 2009; Jenks, 2010).

## 3. Sustainable urban development: a systems approach

A city as a unit composed of a variety of elements connected by all kinds of relations and operating in a specified area and in a specified surroundings, should be treated as a dynamic, functional whole, that is, as a system, and more precisely, a territorial social system. What makes the conception of a territorial social system especially useful with reference to a unit like a city is that it implies efficient control of its territory by the population living in it, which is also a necessary condition for sustainable development (Chojnicki, 1989; Satterwaite, 1997; Mierzejewska, 2009; Vojnovic, 2014).

The basic components of the territorial social system of a city include a social layer, or a community of people together with their needs, endeavours and aspirations, and a material layer together with all its natural and artificial elements, or a territory. Those are not simple components but ones displaying a high level of complexity and numerous internal links. Therefore they can be treated as separate systems (though not territorial ones) while also being social, natural and economic sub-systems of the territorial system of the city. Its structure is formed by relations holding among those sub-systems and their elements, and by their relations with the surroundings. Assuming that the sustainable development of the urban system is intended to ensure it a certain level of balance, putting this conception into practice will mean establishing proper relations in the system. Three types of relations can be distinguished here (cf. Table 2):

- ✓ relations holding within the individual sub-systems (social, economic and natural), i.e. intra-system relations described in Table 2 as $x_{11}$, $x_{22}$ and $x_{33}$ (the principal diagonal of the matrix);
- ✓ relations between the individual sub-systems (social and economic, social and natural, and economic and natural), i.e. inter-system rela-

- ✓ tions described as $x_{12}$, $x_{13}$, $x_{21}$, $x_{23}$, $x_{31}$, and $x_{32}$; and
- ✓ relations with the surroundings, not included in the table because they affect, to a larger or smaller extent, all the other relations listed above.

The causative factor in moulding all those relations, and hence in determining the operation, efficiency and stability (balance) of the entire system, is man, who generates all kinds of economic, cultural and political relations (Chojnicki, 1989, 1999). A key role is played here by people's managerial-organisational work as determined by both, specific political relations and the knowledge of the laws, rules and mechanisms governing the social, economic and natural sub-systems, and relations holding among them. However, people's influence on some of those relations, especially with the surroundings, is only limited, being outside the possibility of direct intervention of persons (including political authorities) controlling the given territorial urban social system, especially in the conditions of a market economy.

Thus, sustainable urban development implies giving a proper form to all the relations mentioned above while accommodating the dynamic nature of the urban system, which is certainly no easy task. What may prove helpful in this respect are various models and conceptions of sustainable urban development presenting concrete measures intended to bring the urban system closer to the state of a balance, although it will always be a dynamic type of balance.

## 4. Models and conceptions of a sustainable city

There are many positions in the literature on the subject describing conceptions or models intended to find proper ways of attaining sustainable urban development, which is perhaps due to the many aspects of this kind of development. When systematising them, however, it is hard to keep to the division into the three types of relations occurring in the territorial social system of a city described in the theoretical part of this paper.

In the output on sustainable urban development most attention is paid to creating an intra-system balance, especially in its economic and ecological aspects. There are also many works dealing with spatial aspects of urban development. Less attention is given to questions of a social and an inter-system balance. Besides, they often do not offer any theoretical approaches to sustainable urban development; rather, they tend to focus on the identification of urban development problems and on how to solve them (Koglin, 2009). While this does not detract from their usefulness, they hardly contribute to a better understanding of the causes underlying the processes that take place in cities and do not indicate long-term goals cities should strive to achieve.

In very general terms, the models and conceptions of sustainable urban development found in the literature can be divided into two groups (cf. Table 3a). The first embraces those that refer primarily to the spatial form of a city in its local and regional aspects, including also an approach combining those two aspects: an eco-city, a compact city, a green city, redesigning a city, an externally dependent city, a Fair Shares (equitable balance) city, MILU (Multi-Functional and Intensive Land Use), new urbanism, and smart growth. Here the discussion is primarily about which spatial-functional structure of a city is the more balanced one: a compact or a more dispersed one, and about ways of attaining such a balanced form.

The other group includes those models and conceptions that basically concern the quality of urban life, in particular in terms of social justice and a balanced urban economy. Here we can find concepts of a self-reliant city, a community garden, a just city, and an XXQ city. Those models, worked out by various authors, e.g. Roseland (1997), Haughton (1997), Nijkamp (2008), etc., are described at length in Mierzejewska (2009).

As follows from a survey of the models and conceptions worked out by the mentioned research streams, the presented classification is not fully disjoint. While the classification criteria are disjoint, what is problematic is an unequivocal assignment of certain models and conceptions to individual classes, mostly because some of them, e.g. those of new urbanism or smart growth, are more universal.

A classification can also be made on the basis of yet another criterion that also yields two groups of models. Those are research streams dealing with: (1) the internal structure of a city, both spatial-functional and socio-economic, and (2) relations between the city and its region (Table 3b).

The first stream is represented by those models and conceptions which focus on intra-urban issues and in which more emphasis is put either on: (1) the spatial-functional structure of a city, including intra-urban ecology, the role of greenery in it, reclamation and renewal of intra-urban areas, etc. (an eco-city, a compact city, a green city, redesigning a city, MILU, and smart growth), or on (2) the quality of life of city residents, social development, and sustainable economic development (a self-reliant city, a Slow City, a community garden, an XXQ city, a just city, and smart growth again).

The other stream includes models and conceptions intended to sort out relations between a city and its suburban zone, mostly by managing its uncontrolled outward expansion, i.e. stopping urban sprawl, and by making relations (links) between the city and its suburban zone more fair. To this group belong the conceptions of a compact city and new urbanism as well as models of an externally dependent city, a Fair Shares (equitable balance) city, and to some extent also smart growth.

The other of the presented approaches is close to two tendencies discernible in the spatial policies of cities,

Table 3a. Classification of selected models and conceptions of sustainable development, own compilation

| Criterion | Models and conceptions |
|---|---|
| Spatial form of a city | - eco-city<br>- compact city<br>- green city<br>- redesigning a city<br>- externally dependent city<br>- Fair Shares (equitable balance) city<br>- MILU (Multi-Functional and Intensive Land Use)<br>- new urbanism<br>- smart growth |
| Quality of life and urban economy | - self-reliant city<br>- community garden<br>- just city<br>- XXQ city |

Table 3b. Classification of selected models and conceptions of sustainable development, own compilation

| Criterion | | Models and conceptions |
|---|---|---|
| proper internal structure | spatial structure | - eco-city<br>- compact city<br>- green city<br>- redesigning a city<br>- MILU (Multi-Functional and Intensive Land Use)<br>- smart growth |
| | socio-economic structure | - self-reliant<br>- slow city<br>- community garden<br>- XXQ city<br>- just city<br>- smart growth |
| proper relations between city and its region | - externally dependent city<br>- Fair Shares (equitable balance) city<br>- smart growth | |

sometimes termed *ecology within a city* and *the city in ecology* in the literature (Næss, 2001). One refers primarily to the traditionally understood protection of the urban environment and embraces such issues as care for a high quality of the air, the quantity of drinking water supplied to residents, and green areas in a city, which of course are still very important. In the other the city is perceived as part of a larger ecosystem, hence what is taken into consideration when planning its development are its relations with both, the immediate and a farther vicinity, and in the case of large metropolises, even international and global influences (Fig. 1).

A look at a city from a broader perspective than a local one has attracted the interest of many scholars, like Wong and Tang (2005), Kowalewski (2005), Olewiler (2006), Pincetl (2012), or Cobbinach et al. (2015). Naturally, those two approaches (*ecology within a city* and *the city in ecology*) are not mutually exclusive. What is more, it seems that the assumptions of sustainable urban development require a simultaneous adoption of both.

The perception of ecological relations in an urban system has consequences in its compact or dispersed building pattern and its spatial-functional structure resulting from the development model adopted. Each of the models considered sets different directions in the planning of the spatial structure of newly built-up urban and suburban areas, which in turn crucially influences the sustainability conditions of the city (see Jenks, 2010). Each also has advantages and disadvantages that should always be considered in terms of the basic goals of sustainable development. In general, those goals are often reduced to the following (Næss, 2001; Mierzejewska 2006):

1) reducing per capita energy consumption in an area (e.g. a city) to a level meeting the criteria of the division of the Earth's ecological capacity at the global scale,
2) reducing the transformation of natural ecosystems and agricultural production spaces into investment areas,
3) minimising the consumption of materials detrimental to the environment,
4) replacing open cycles (linear metabolism) by closed cycles (circular metabolism), additionally designed to rely on local resources (Girardet 1992, 1993),
5) creating a healthy living environment for city residents (without pollution, noise, with a suitable number of green areas to help them keep emotional links with nature), and

6) creating a suitable social environment ensuring social development and affecting moral-ethical attitudes.

However, authors differ in what they see as goals or principles of sustainable urban development. According to Gibbs (2000), the chief principles of sustainable development are:

- ✓ quality of life (including and linking social, economic and environmental aspects),
- ✓ care for the environment,
- ✓ thought for the future and the precautionary principle,
- ✓ fairness and equity, and
- ✓ participation and partnership.

A slightly different, more ecologically oriented approach is taken by Heinberg (2010), who lays down five *axioms of sustainability*:

1) any society that continues to use critical resources unsustainably will collapse,
2) population growth and/or growth in the rates of consumption of resources cannot be sustained,
3) to be sustainable, the use of renewable resources must proceed at a rate that is less than or equal to the rate of natural replenishment,
4) to be sustainable, the use of non-renewable resources must proceed at a rate that is declining, and the rate of decline must be greater than or equal to the rate of depletion,
5) sustainability requires that substances introduced into environment from human activity be minimised and rendered harmless to biosphere functions.

However, this approach refers primarily to the sustainability of development which, as has already been mentioned, is a concept hard to use with reference to a unit like a city (Satterhwaite, 1997; Mierzejewska, 2015). A similar opinion is expressed by Koglin (2009), who claims that it is the global system that should be sustainable, which means that its individual parts need not be sustainable. What should be established are proper relations both within the system of a city and between the city and its surroundings, as treated more broadly by, e.g. Næss (2001).

The presented models and conceptions determine concrete measures that have to be taken in order to ensure each city a sustainable /balanced type of development. They involve:

- ✓ increasing the density of the population and buildings, but only to a level that would still guarantee its residents a high quality of life,
- ✓ mixing various land uses, naturally only up to a point when an excessive accumulation of various functions in an area could produce spatial chaos,
- ✓ revitalising degraded and dysfunctional areas,
- ✓ expanding urban greenery,
- ✓ moulding the city's spatial order, including its design and architecture,
- ✓ developing balanced forms of transport (public, bicycle, pedestrian traffic),
- ✓ a modern system of waste collection, management and recycling,
- ✓ efficient energy management, including the use of renewable sources of energy and reducing heat losses (e.g. via thermal modernisation of buildings, the replacement of window frames), and
- ✓ increasing a city's diversity (primarily social, but also in its land-use pattern and in the natural sphere),
- ✓ the planning process accommodating the needs and opinions of all social groups, especially those that are weaker, poorer, etc.,
- ✓ better access of residents to high-quality public areas,
- ✓ increasing the city's self-reliance and its endogenous growth,
- ✓ supporting the local market, local products, traditions, etc.,
- ✓ developing social infrastructure favourable to the cultural development, innovativeness, creativity and entrepreneurship of residents, and
- ✓ developing an innovative economy based on knowledge and using modern computer techniques.

The above measures should help to improve the quality of life of city dwellers and ecological conditions in the city, and to reduce its transport needs and the dependence of the urban economy on its surroundings.

Among the above measures for the sustainable development of a city there is a high proportion of those concerning its spatial form. Making the spatial-functional structure of a city conform to sustainable development standards requires the adoption of a suitable development policy which, however, cannot be restricted to the planning of proper intra-urban relations, but should also see the city as an element of a larger ecosystem. Generally, the target is a compact city, but one that would guarantee a high share of green areas in the urban structure, easy access of inhabitants to physical and social infrastructure, and efficient transport networks, primarily public.

Giving a city a balanced form requires its authorities to work out a spatial development policy that will allow (Mierzejewska, 2007):

- ✓ increasing the height of buildings in the suburban zone and the population density in the city centre;
- ✓ giving existing buildings new users,
- ✓ regulating transport issues, especially giving priority to public transport, reducing transport-related areas (especially car parks), and constructing more walking and biking paths,
- ✓ changing the rules of developing suburban areas (e.g. by giving fewer permissions for building free-standing houses on individual lots, reduced funding of physical infrastructure, reducing transport-related areas, especially car parks),

and

- ✓ introducing public spaces to housing estates, primarily parks and recreation grounds that will allow their residents to engage in active and passive forms of recreation and establish social contacts.

Those are measures that will simultaneously boost the city's social productivity and economic efficiency while taking care of its natural environment and spatial order. However, what is crucial in sustainable development is not only setting proper development objectives, but also obtaining social acceptance for them, which may turn out to be very difficult (Mierzejewska, 2009). For many inhabitants of modern cities the ideal is often still a house with a garden in the suburbs and the freedom of going to places of goal attainment in a private car (Koglin, 2009).

## 5. Conclusions

The most popular way of understanding sustainable development is that given in *Our Common Future* (WCED, 1987). It seems hard, however, to apply it to a city, especially its management within limitations imposed by the natural environment. In the modern world, a city, especially a large one, is a supra-local central place performing the function of a driver of economic growth, and as such it has to rely on the ecological capacity of its immediate and farther hinterland. For this reason it is advisable to treat a city as a complex territorial social system in which the key role is played by a community controlling the territory it inhabits and the sustainable development of which is determined by a dynamic intra- and inter-system balance and a balance in its relations with the surroundings.

Some suggestions as to how to approach relations occurring within an urban system can be found in various models and conceptions of its sustainable development. Their abundance shows that there is no single, universal, correct model of urban development, a consequence of which is the necessity to seek a sustainable development path for each city separately.

Planning the sustainable development of a city requires an exact knowledge of individual elements of the urban system and the network of relations holding among them, the adoption of some assumptions and goals designed to achieve a balance in it, and an adjustment of those assumptions to local conditions. Therefore it is impossible to replicate even the most successful solutions worked out for a different geographical, natural, political, or socio-economic reality. Even so, it seems worth making use of theoretical achievements and practical experiences of individual countries and cities, both in moulding the spatial form of a city and in improving the quality of life of its dwellers and its economic conditions. In the first case, the chief aim is curbing its spatial expansion by building a compact city and organising multi-functional quarters and housing estates within it, and in the latter case the focus is on a high quality of life of its dwellers, and this mainly involves a high quality of the natural environment and access to various types of goods and services, including public spaces. Naturally, of no little importance in such a balanced city is the empowerment of its residents and concern for a high level of environment-friendly economic development. Still, one should keep it in mind that this will always be a dynamic equilibrium.

## References


1. BORYS T. (ed.), 1999, *Wskaźniki ekorozwoju* (Indicators of eco-development). Białystok: Wydawnictwo Ekonomia i Środowisko
2. BUGGE H.C., WATTERS L., 2003. A perspective on sustainable development after Johannesburg on the fifteenth anniversary of 'Our Common Future', An interview with Gro Brundtland. In: *Georgetown International Environmental Law Review*, 15, p. 359-366
3. CHOJNICKI Z., 1989, Koncepcja terytorialnego systemu społecznego (Conception of a territorial social system), in: *Przegląd Geograficzny*, 60 (3), p. 491-510.
4. CHOJNICKI Z., 1999, Koncepcja terytorialnego systemu społecznego, in: ed. Czyż T., *Podstawy metodologiczne and teoretyczne geografii*, Bogucki Wydawnictwo Naukowe, Poznań.
5. DOMAŃSKI R., 2006, *Geografia ekonomiczna. Ujęcie dynamiczne*, PWN, Warsaw.
6. GIBBS D., 2000, Ecological modernisation, regional economic development and regional development agencies, in: *Geoforum*, vol. 31 (1).
7. GIRADET H., 1992, *Cities: New directions for sustainable urban living*, Gaia Books, London.
8. GIRADET H., 1993, Sustainability: The metabolism of London, in: *Regenerating Cities* 6, p. 37-40.
9. HAUGHTON G., 1997, Developing sustainable urban development models, in: *Cities*, vol. 14 (4).
10. HEINBERG R., 2010, *What is Sustainable City?* The Edmonton Sustainability Papers.
11. JENKS M., JONES C., 2010, Issues and Contepts, in: *Dimensions of the Sustainable City*, eds.Jenks M., Jones C., Springer, London – New York, p. 1-19.
12. KOGLIN T., 2009, *Sustainable development in general and urban context: a literature review*, Bulletin – Lund University, Lund,
13. KOWALEWSKI A.T., 2005, Rozwój zrównoważony w procesach urbanizacji, in: *Nauka* 1, p. 123-146.
14. MIERZEJEWSKA L., 2006, Rola planowania przestrzennego w rozwoju zrównoważonym

miast, in: Słodczyk J., Rajchel D. (eds.), *Polityka zrównoważonego rozwoju oraz instrumenty zarządzania miastem* Uniwersytet Opolski, Opole, p. 11-28.
15. MIERZEJEWSKA L., 2009, Urban planning in Poland in the context of European standards, in: *Questiones Georgaphicae* 28B(1), p. 29-38.
16. NAESS P., 2001, Urban planning and sustainable development, in: *European Planning Studies* 9 (4), p. 504-524
17. NIJKAMP P., 2008, XXQ Factors for Sustainable Urban Development, in: *Romanian Journal of Regional Science*, vol. 2, p. 1-34.
18. NORGAARD R.B. 1989, The case of methodological pluralism, in: *Ecological Economies* 1, p. 37-57.
19. OLEWILER N., 2006, Environmental sustainability for urban areas: The role of natural capital indicators, in: *Cities*, vol. 23 (3), p. 184-195.
20. PETRISOR A.I., PETRISOR L.E., 2013, The shifting relationship between urban and spatial planning and the protection of the environment: Romania as a case study, in: *Present Environment and Sustainable Development* 7(1), p. 268-276.
21. PINCETL S., 2012, Nature, urban development and sustainability – What new elements are needed for more comprehensive understanding?, in: *Cities*, vol. 29, p. 532-537.
22. OSELAND M., 1997, Dimensions of the eco-city, in: *Cities*, vol. 14 (4).
23. SATTERHWAITE D., 1997, Sustainable Cities or Cities that Contribute do Sustainable Development?, in: *Urban Studies*, vol. 34 (10), p. 1667-1691.
24. SNEDDON C., HOWART R.B., NORGAARD R.B., 2006, Sustainable development in a post-Brundtland world, in: *Ecological Economies* 57, p. 253-268.
25. VOJNOVIC I., 2014, Urban sustainability: Research, politics, policy and practice, in: *Cities*, vol. 41, p. 530-544.
26. WCED (World Commision on Environment and Development, Brundtland Report), 1987, *Our Common Future*. Oxford University Press, New York 1987.
27. WONG S., TANG B., 2005, Challenges to the sustainability of 'development zones': A case study of Guangzhou Development District, China, in: *Cities*, vol. 22 (2), p. 303-316.

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# Rationalisation of Investment Decisions in the Sustainable Management of Urban Development – is a New Paradigm Needed?

# Racjonalizacja decyzji inwestycyjnych w zrównoważonym zarządzaniu rozwojem miast – czy jest potrzebny nowy paradygmat?

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## Abstract

The management of dynamic and complex urban systems can no longer be driven by the sustainability aim alone and the concept of *New Public Management* is not more sufficient in conditions of financial constraints, growing needs, growing social awareness and expectations relating participation, citizenship, and public accountability. The general aim of the paper is to bring different concepts together to propose a new approach to investment decision making in urban development in order to support cities on both strategic and operational level. The rationalisation of investment decisions in the management of urban development requires acceptance of a new paradigm combining ideas of sustainable development and smart city, triad of *creativity – circularisation – synergy*, stakeholder theory, and social responsibility. The rationalisation requires also application of multi-criteria analysis which takes into account *cross* nature of investment in urban development. The proposed approach may be a theoretical reference for the subsequent methodological research and also managerial applications relating urban development projects. It can be then useful for public managers and provide support for decision making. The innovative approach of the research is not based on inventing new ideas from the scratch. It concerns application of already known concepts and theories which are necessary to create a new paradigm consistent with the known facts. The research is based on a critical literature review.

**Key words:** sustainable development, smart city, urban development, public management, planning, investment evaluation

## Streszczenie

W warunkach ograniczeń finansowych, rosnących potrzeb i świadomości oraz oczekiwań w zakresie uczestnictwa, obywatelstwa i publicznej odpowiedzialności, zarządzanie dynamicznym i złożonym systemem miejskim według koncepcji rozwoju zrównoważonego i zgodnie z zasadami *New Public Managment* (nowego zarzadzania publicznego), jest już niewystarczające. Głównym celem artykułu jest synteza różnych koncepcji, tak by na ich bazie zaproponować nowe podejście wspierające podejmowanie decyzji inwestycyjnych zarówno na poziomie strategicznym i operacyjnym. Racjonalizacja decyzji inwestycyjnych w zakresie zarządzania rozwojem miast wymaga akceptacji nowego paradygmatu łączącego idee zrównoważonego rozwoju i inteligentnego miasta, triady *creativity – circularisation – synergy (kreatywność – cyrkulacja – synergia)*, teorii interesariuszy i odpowiedzialności społecznej. Racjonalizacja wymaga również zastosowania analizy wielokryterialnej, która uwzględnia dwojaki charakter inwestycji w rozwoju miasta. Proponowane podejście może być teoretycznym odniesieniem dla dalszych badań metodologicznych, a także może znaleźć zastosowanie w zarządzaniu projektami w rozwoju miasta. Kon-

cepcja, dostarczając wsparcia w procesie decyzyjnym, może więc być użyteczna dla menedżerów w sektorze publicznym. Innowacyjność rozwiązania nie opiera się na stworzeniu nowej koncepcji od podstaw. Polega na zastosowaniu pojęć i teorii znanych, które są niezbędne, aby stworzyć nowy paradygmat, zgodnych z faktami. Artykuł opiera się na krytycznym przeglądzie literatury.

**Słowa kluczowe:** zrównoważony rozwój, inteligentne miasta, rozwój miasta, zarządzanie publiczne, planowanie, ocena inwestycji

## 1. Introduction – research justification, aim and methodology

Urbanisation is believed to be an area of significant civilizational changes), as the future of humankind is linked with cities. No more than 5% of the world population lived in the cities in 18th century, while today it is more than 50%, and United Nations forecasts (2014a) that more than 80% of the population will live in urban area by the end of this century. That determine necessity of cities development and re-development. The city development/re-development management relates to use of scares resources and transformation of the existing state to desired one. The management relates to economic, social, technological, and natural systems. The city development and investment management means space management as city is both a physical place of paths and buildings, and also a space of values, beliefs, and relations. The general aim of the city development management is to ensure sustainable development which is manifested by an increase in national income, qualitative changes in the structure of the economy, availability of goods and services for citizens, better standard of living. But translating this concept into action is a challenge. On the strategic level the management means outlining goals at future requirements. It is master planning on the tactical level, and finally, planning, implementation, and evaluation of urban development project on the operational level (Girard, Nijkamp, 1997). The first step, at the strategic level, is to improve competitiveness. At the level of master planning, evaluation mainly focus on land use choices. Finally, on the operational management level, evaluation refers to new investment projects. It is the public sector who is by law responsible for the urban economy as all levels. That is why management relates also to the institutional level. Then, government strategies must provide effective public resources management with respect to the sustainable development which means allocating their resources among different goals (projects) rationally. When the sudden credit crisis from 2008 and the subsequent recession in many national economies happened, new challenges for cities and policy makers arose across the world (Flint, Raco, 2012). The city strategies and planning assumptions were challenged as the prosperity were downsized, and the private and public sector investment became more constrained. A new situation connected with public finance consolidation emerged (Ministry of Economy, 2012) and it has been shaping the determinants of investment management and criteria for their evaluation since then.

The paper focuses on the investment decision in the management of the urban development and is justified by the necessity of scarce resources rationalisation which is a principle of sustainable development. The scarce resources relates to natural environment resources, space within the cities, financial resources, and the creative capital of the city as well. The sustainability then relates to balance between economic, social, technical, and natural systems. Talking about build environment, the balance relates to satisfying needs concerning different types of infrastructure and investment, too. In the wider context, it relates to balance between *hard* components and *soft* values. In consequence, cities have to act much smarter in using the existing capacities and resources. These call for changes in the investment planning and evaluation. The problem is intensified by the absence of proper organisational structures, processes of reforms in the public sector administration, and growing civil society. These call for organisational changes as management relates also to institutional level. Therefore, the management of the dynamic and complex urban systems can no longer be driven by the sustainability principle and New Public Management concept alone.

The thesis of the paper states that in order to ensure sustainable development in four dimensions (in relation to resources; in relation to economic growth, social justice and protection of environment; in relation to different types of the infrastructure; and in relation to *hard* and *soft* component), the management of city investment must be accompanied by idea the of smart development, concept *of creativity – circulation – synergy*, and social responsibility, with respect to all stakeholders.

The second section of the paper presents literature review relating investment management in the public and private sector to picture the background for the research. The interactions between the sectors gave rise to new concepts.

In the third part of the paper the framework of decision making rationality on strategic level is described. The proposed new approach to the investment decision making rationality in urban development is the starting point to make a breakthrough in the city investment management. The proposition combines ideas of the sustainable development and smart cities. Additionally, the principles of creativity, circularization, and synergy, adopted from L. F. Girard (2011), are included. Those principles are in

line with the old concept of P. Geddes (1915) who interpreted city an organism in evolution. Next, stakeholder theory and renewed social responsibility are encompassed as well. The connections between mentioned concepts in the relation to the proposed approach are explained. The fourth section transfers the concept on the operational level. The paper is closed with conclusions which also includes identification of a new type of *cross* investment as a consequence of the proposed approach.

The paper offers an insights into the public investment management, emphasises the role of the investment planning and evaluation to enhance sustainability and smartness of the city. It is in line with other recent studies relating public management and focuses on the search of new approach to investment management in urban development. The proposed approach may be viewed as a theoretical reference for the future methodological and operational applications relating urban development projects. It can be then useful for public managers and provide support for decision making in that area.

The research is based on a literature review. For study justification, reports relating public finance and urbanisation were studied. For the conceptual part of the research, the literature of public sector management, business management, and investment management were also studied.

## 2. Literature review – public versus business management

Significant achievements of the economic science in the field of business management have provided an incentive to use this field in local government (municipal) investment management. Still, a new stream of economic knowledge is under-utilised in the field of municipal investment. The category of public real estate development is often separated from the category of private real estate development and the public sector is alienated from the private. The identified gaps concerns strategy, portfolio, finance, organisation (Wojewnik-Filipkowska, Rymarzak, Lausberg, 2015). The approach to public management, as to the business management, is not easy because of the specific sources of public investment financing, but also due to the specific nature of the effects created by the public investment. These effects are not easily measured in terms of money, and verifying their quality encounters significant difficulties. According to R. P. Appleby (1949) there are three important aspects which make the public management different from business management: the political character, the impact, and public accountability. J. Stamp (1923) adds principle of uniformity, external financial control, and service motive. P. F. Drucker points out (1973): needs, values, objectives, contribution, and measurement as differences. H. Simone (1946) said that the public administration is bureaucratic, political, and characterized by *red-tape*, while private administration is more business-line, non-political, and free of *red-tape*. Particularly, the public and private sectors are definitely diverse in case of their investment aims (Atkinskon, Stiglitz, 1980; Boland, Flowler, 2000; Alford, 2001). Traditionally, the public sector has had social (public) aims and the private sector has had financial (commercial) aims, but, all in all, both sectors play important roles in city development. So, despite mentioned differences, in many developed countries, current trends of the theory of business have penetrated into other spheres of the economy and society, and public administration have been deeply transformed especially in modern economies. There is growing interest in strategic management in the public sector despite the implementation challenges (Bouckaert, 1993; Chan, 1999; Poistert, Streib, 1999; Yang, 2007; Sienkiewicz, 2013), while twenty years ago, managerial topics were not discussed in public management, at all (Wojewnik-Filipkowska, Rymarzak, Lausberg, 2015). The more developed and mature country's economy, especially its capital market, the faster the process of contemporary economic trends dissemination. The sphere of the infrastructure investments is also involved. For instance, the United Kingdom is the leading country in terms of implementing private sector achievements in the public sector through public private partnership (HM Treasury, 2012). According to O. Kaganova (2011) some solutions and practices can be transferred across countries with respect to country culture, tradition, and law. The public sector can learn from the private sector's best practices in real estate asset management for instance (Phelps, 2010; White; 2011; Hirigoyen, Laouer, 2013) but simultaneously business process reengineering in public sector has been criticised (Halachmi, 1996; Radnor, Osborne, 2013). It means that public sector investment management requires continuous research for new solutions and new approaches. It was already in the eighties of 20th century, when *the group of ideas known as New Public Management* (NPM) emerged (Hood, 1991, p. 3). Since then, despite some critiques, NPM has been a concept implemented globally to make the public sector more business-like (Box et al., 2001). NPM, known also as a market management, borrows a number of solutions typical for the market economy and the private sector and adapts them to the public sector. The solutions are: managerial approach, results orientation, decentralisation, privatisation and outsourcing, focus on manager's personal responsibility, flexible employment, work organisation and structures, as well as improvement of asset management, efficiency and effectiveness (Andrisani, Hakim, Savas, 2002). Other terms that have been used to describe the NPM model include: (public) managerialism, market-based public administration, entrepreneurial government, and business-like management. And just after NPM became a worldwide phenomenon, we have to move beyond, as pointed

out by several authors (Stoker, 2006; Osborne, 2010; Bryson, Crosby, Bloomberg, 2014; Fisher, 2014; Kalambokidis, 2014). According to J. M. Bryson et al. (2014, p. 445): *The new movement is a response to the challenges of a networked, multisector, no-one-wholly-in-charge world and to the shortcomings of previous public administration approaches*. Furthermore, values of democracy are getting more important than efficiency and effectiveness. Citizens, all together with business and non-profit organizations, are becoming active public solvers, while government must remain a guarantor of public values.

## 3. Decision making rationality of investment in city development – new approach (strategic level)

Based on the development of traditional public administration and business management dimension of NPM, a new approach to rationality of investment management in city development must be recognised and focused on the impact and future. There are three interconnected *threads* forming the emerging approach. Firstly, as stated in thesis, the emerging approach should incorporate the concept of sustainable development and smart cities. Furthermore, the principles of creativity, circularization, and synergy, must be included. Finally, stakeholder theory and principles of social responsibility, must be taken into consideration. These concepts are not new in public sector however their combination may become a reference for the methodological and strategic applications concerning urban development projects.

### *3.1. Sustainable (and) smart development*

Sustainability is an area of increasing focus for policymakers (Zeemering 2009; Nijaki, Worrel, 2012). Sustainable development is a *development that meets the needs of the present without compromising the ability of future generations to meet their own needs* (WCED, 1987, p. 16). In other words, sustainable development means that the needs of the current and future generations are balanced. The term focuses on the *needs* – however might be defined. According to United Nations (2014b) it comprises 169 goals and targets within 17 directions, while for instance M. Leźnicki and A. Lewandowska (2016) distinguish 21 aspects in 3 dimensions. Recently however there has been a shift towards *rights*. Therefore, sustainable development should be interpreted in terms of *integrated* order: *pursuing economic growth as well as protecting our natural capital and promoting social justice* (Eurostat, 2015, p. 4).

In reference to sustainable investment management, it can be subtracted, that the balance between different types of infrastructure investment is needed. Traditionally, the infrastructure comprised of economic (technical) and social infrastructure. Economic infrastructure includes development relating to energy, transportation and communication, water and sewage. Social infrastructure embraces social system (education, culture, health, social service and recreation) and institutional system (public order and administration, e.g. justice, police, army, and prison). Taking into consideration public and private investment in the build environment and city smart development, we have to distinguish the third type of infrastructure. It relates to institutional support for business environment. The infrastructure of business environment includes special investment zones, science parks, centres of technology transfer, incubators. Based then on the mentioned description relating sustainability, two dimensions of sustainable development can be identified: as a balance between economic, social and natural systems; and secondly, as balance between social, economic (technical), and business environment infrastructure. In a richer meaning, the sustainable development relates to *hard* component (e.g. number of jobs created) and *soft* values (e.g. value of land scape). According to L. F. Girard (2013) the development of *soft* components has not been up with *hard* values as large economies got richer but produced negative effects such as ecologic poverty, unevenly effective education and health care system, deepening inequalities, a stagnant middle class. Finally, the fourth dimension of sustainability means that the balance between different resources/capital (natural, economic, human, and social) must be achieved.

These restricted resources, in particular social and human capital, connect the concept of sustainable development and smart development. It means that cities (by their social and human capital) in their sustainable development, have to act smarter. However *smart* development is not based only on innovative technologies (Girard, 2013), as intuitively it might be concerned. The prime association is innovative (smart) technology. So yes – smart city is to promote the use of modern technology in everyday urban life, for instance transport technologies which improve the urban traffic and the inhabitants' mobility. In the relation between the city government, administration and citizens – *smart* often means the employment of new channels of communication (e.g. e-government). In association with economy or jobs, *smart* is related to business of information and communication technologies (ICT) and business parks creation. But as the term *smart city* has been widely used in urban planning literature and urban research, but it is not presented in a holistic way (Giffinger, 2007). It comprises various aspects. *Smart* relates also to education, security, green, efficient & sustainable energy. According to study by R. Giffinger et al. (2007), the concept of smart cities embraces following smart aspects: economy (competitiveness), people (social and human capital), governance (participation), mobility (transport and ICT), environment (natural resources), and living (quality of life). M. J.

Dixon (2012, p. 2) can be cited to confirm the connection of the concept of smart cities and sustainable development: *Instead of striving for physical growth, a city's success today should be measured by how wisely it uses energy, water, and other resources, how well it maintains a high quality of life for its people, and how smart it is in building prosperity on a sustainable foundation*. In other words, smart city concept embraces social and human capital aspects (the *source* of *smartness*), and sustainability (Hollands, 2008). Then, it can be claimed that the concepts of sustainable and smart development are inter-related and inter-connected and a term of sustainable smart development is justified. The triple helix model of smart cities performance proposed by P. Lombardi et al. (2011), including human and social relations, confirms the observation of smart and sustainable connection.

*3.2. Creativity, circularization and synergy*

As explained above, in reference to sustainability in terms of resources, social and human capital is a resource that must be balanced. In reference to smart city – human and social capital are a part of a smart city aspects and the source of creativity. Social and human capital is then an important connection between sustainable smart development and creativity in the *synergy – creativity – circularization* triad. Creativity is an immaterial capital of all inhabitants which enables cities to face the economic challenges, environmental crisis, urban marginality and poverty, growth of inequalities. The creative capital is an asset which reflects citizens' lifestyles, their relationships, and economic performances. It can take a form of new financial and institutional systems, architectural and planning re-design of the city, new technologies, and innovative networks among public, private and civic sectors. Creativity means also integrating old values into a modern vision. It also means integration of objectives of economic, social and ecological performance. Therefore is allows to overcome the traditional trade-off and achieve win-win solution. Creativity enables self-organization capacity, too, and therefore a continuous creation of new opportunities which is a condition for in-side city resilience is possible (Girard, 2011).

The circular opportunity of urban regeneration in the development process is then enabled particularly due to creativity (Zeleny, 2010; Girard, 2011). As urban regeneration calls for re-use and recycle of resources, circularisation is also in line with *ecological* sustainability. There is an evidence of good practices relating cultural heritage and recreation which become an important local development resource in the economic regeneration process (Girard, 2011). The circulation relates also to urban resilience understood as a capability to survive different crises or sustain competitive advantage (Simmie, Martin, 2010). According to J. Bloesch et al. (2015), the concept of resilience integrates sustainable development. M. Baron (2012) lists several perspectives within urban resilience: technical (infrastructural), economic (financial), social, natural. The circulation relates also to *value* which circulates around the city and layers of city governance (Ravetz, 2011). The layers relate among others to economic, social and technological decision making. Decision makers will get involved in the urban development, if it offers them value. The circulation of the value is possible due to different understanding of the *value* which corresponds with different understanding of needs.

Finally, the principle of synergy applies to interrelations of city systems: urban, economic, social, cultural, political, ecological, and governmental. Each of the systems are interconnected and synergies opportunities (value-added) appears beyond boundaries. For instance, the *urban – economic – social* synergy can be in the following path: *urban climate policy – spatial planning – creative regeneration – building design – resource recycling – sustainable consumption – prosperity & well-being – community development – social synergy* (Ravetz, 2011). According to the principle of synergy, the process of management and eventually the quality of this space depends also on synergies among various actors (stakeholders). The residents, users, administration, visitors, industry are the main stakeholders. Each of them however, sees the space and its value differently, as stated above, but the sustainable smart approach allows to avoid trade-offs between their aims according to stakeholders' power, legitimacy, and urgency which will determine their impact over urban development.

*3.3. Stakeholder theory and social-business responsibility*

According to the triad *creativity – circularization – synergy*, different understanding of *value* allows its circularisation. J. M. Bryson et al. (2014) claim that this heterogeneity is a result of the perspective adopted by the stakeholder, for whom a given benefit is available. So stakeholders must be components of the triad. Inhabitants are no longer simply voters or clients, but are also co-decision-makers, contributing to the creation of common wealth. Therefore, an effective urban development policy is a result of decisions made by specialists, with due attention paid to a wide range of social groups, their participation and engagement. The stakeholder theory emerged in this context (Freeman, 1984). A stakeholder is anyone who significantly influences decision-making or is affected by the decisions made. Stakeholders' power is determined by whether the stakeholder can influence other parties to make decisions which that party would not otherwise made. The legitimacy means that the stakeholder has a legal, moral, or other recognized claim that can influence the organization's

decision, behaviour, process or outcome. Finally, urgency, requires organizations to respond to stakeholder claims in a timely manner (Mitchell, Agle, Wood, 1997). Participation of the stakeholders is the central issue of our time (Jones, 2003). M. Lyons et al. (2001) argue that empowerment will develop if people receive training. Then, fully empowered people and/or communities will be able to contribute towards sustainable development.

A. Pawłowski (2008) provides evidence that principle of sustainable development is a principle of differential responsibility. And so the social responsibility is a concept in which social and environmental criteria are voluntarily taken into account in business operations and relations with interested parties (stakeholders) (Commission of the European Communities, 2001). From the perspective of investment in city development, the concept will be renamed as social-business responsibility, as also public sector (socially focused), has to take under consideration business aspects. There are three aspects within the responsibility concept that should be distinguished (Fontaine, Haarman, Schmid, 2006). They form a *bridge* between public sector (administration and citizen) and business. The first aspect relates promotion of ethics in business. Decision-making should regard the needs of future generations (the sustainable development aspect). It imposes a moral obligation on business to operate ethically. The second aspect states that business and public sector both represent the same interests, differing only in their organisation. According to the third aspect, public administration is obliged to take into account expectations of all the stakeholders.

Although social responsibility and sustainable development concepts are based on different theoretical grounds, they both aim to improve the life quality. The concept of social-business responsibility can then contribute to creation of creativity, support city resilience, and finally, sustainable smart development.

Concluding the section over concept and theories constituting new paradigm, there are principles for rational decision making in public investment: sustainable development, smart development, creativity – circularisation – synergy triad, stakeholder theory, and social-business responsibility. *The smart sustainable city is a city where economic, social and environmental values are achieved in an efficient and balanced way, able to last over time. A general characteristic of a smart sustainable city is the capacity to contribute to closing the flows of resources through circularized processes, and to activate synergies between actors or institutions in a win-win perspective* (Girard, 2013, p. 4333). Furthermore, *A smart sustainable city (SSC) is an innovative city that uses information and communication technologies (ICTs) and other means to improve quality of life, efficiency of urban operation and services, and competitiveness, while ensuring that it meets the needs of present and future generations with respect to economic, social and environmental aspects* (ITU, 2014, p. 13). The creativity – circularization – synergy triad constitutes the principles, too, although it is not clear whether creativity activates synergistic and circular approach, or synergistic and circular approach activate creativity. It is however clear that the creativity does not relate only to technological innovations but also to city organisation and management connected with social-business responsibility and all stakeholders' participation. These all make urban development projects planning and evaluation to be a challenge in the process of implementing the strategy via investment project management on the operational level. Figure 1 one illustrates the content of new paradigm on the strategic level.

Once the new paradigm of the investment decision making rationality in urban development on the strategic level has been formulated, we need to operationalise the strategy on the lower level of management (operational level).

## 4. The process of investment planning and evaluation (operational level)

Planning and decision-making are fundamental functions in the management process (Griffin, 2002). Planning is a process based on goals, facts and well-considered evaluation. It is a process of deciding what to do and how to do it before a decision is made. It means that planning encompasses defining goals, determining strategies of achieving them, and developing a cohesive hierarchy of plans designed to integrate and coordinate the activities (Robbins, DeCenzo, 2005). This is how planning contributes to decision-making - it consists of successive, logically structured activities, between which a cause-effect relation exists, and the final effect of which is an ultimate decision.

A general model of investment planning consists of several phases. Because investment project management is based on the assumption that the projects are of cyclical nature, these phases fit into a universal investment process model. This model was developed by United Nations Industrial Development (UNIDO) (Behrens, Hawranek, 1991) and includes three stages: pre-investment, investment and operational. Simultaneously, the European Union has developed its own concept of project life cycle (European Commission, 2005). Both approaches require input, criteria and output, as shown in the table 1.

Investment determinants (input) are classified in the literature as tangible and intangible, quantitative and qualitative, or hard and soft. According to urban development projects, the determinants can be social or cultural; legal or institutional; and political, economic, financial, urban or ecological (Wojewnik-Filipkowska, Rymarzak, 2013). The evaluation criteria (for ex-ante analysis) are the core of the selection stage. The criteria are dependent variables by

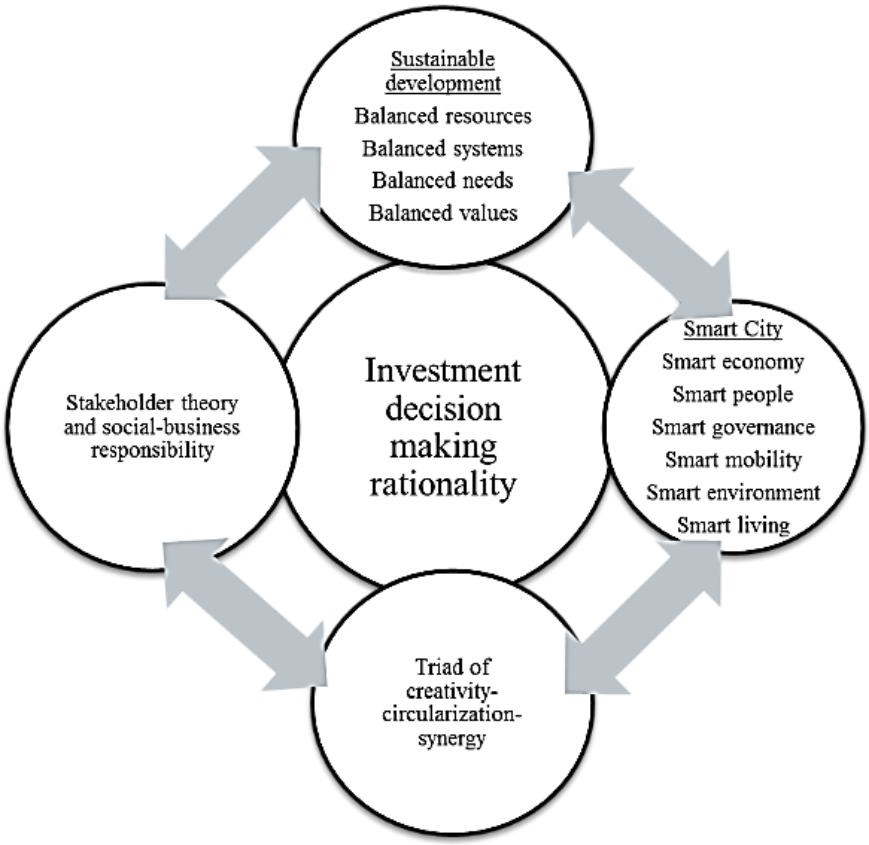


Figure 1. New paradigm of the investment decision making rationality in urban development – strategic level, source: Author's own work

Table 1. Framework of investment planning process, Author's own work

| | **Preparatory stage** | **Selection stage** | **Control stage** |
|---|---|---|---|
| **UNIDO model** | 1) Identification of the goals.<br>2) Analysis of resources & goal determinants.<br>3) Establishing criteria & preparing the resources.<br>4) Determining solution variants. | 5) Application of decision-making criteria.<br>6) Assessment, comparing & selection.<br>7) Formulating the decision.<br>8) Carrying out the plan. | 9) Control of results. |
| **EU model** | I. Programme.<br>II. Identification.<br>III. Formulation.<br>IV. Commitment & appraisal. | V. Implementation. | VI. Evaluation. |
| ***Assumptions*** | *Input (determinants; e.g., resources)* | *Criteria (derived from aims and their measurements)* | *Output (products, services coherent with aims)* |

which the output is judged (Węgrzyn, 2016). The *value added* is a criterion in most investment decision making (Boardman, Greenberhg, 2001; Sayce et all., 2006). From a broader perspective, added value should include external effects, such as the impact of the decision on the agent, synergies with other decisions, the creation of long-term development opportunities, and costs and benefits distribution among stakeholders. Then, output are products and services generated due to the investment programme and plan. Output must be coherent with the identified aims and measurements. Finally, urban development projects' results should be monitored and ex-post evaluated in order to improve process of investment management and stimulate development of new solutions derived from experience. For the purpose of evaluation, a set of understandable indicators communicated to all stakeholders is needed. These criteria should be included into multi-criteria evaluation in order to promote creativity, encourages stakeholders' involvement, and overcome traditional trade-offs (Girard, 2010). Ex-ante evaluation on the operational level of urban development, is *simply* to answer which project sustains the growth of urban

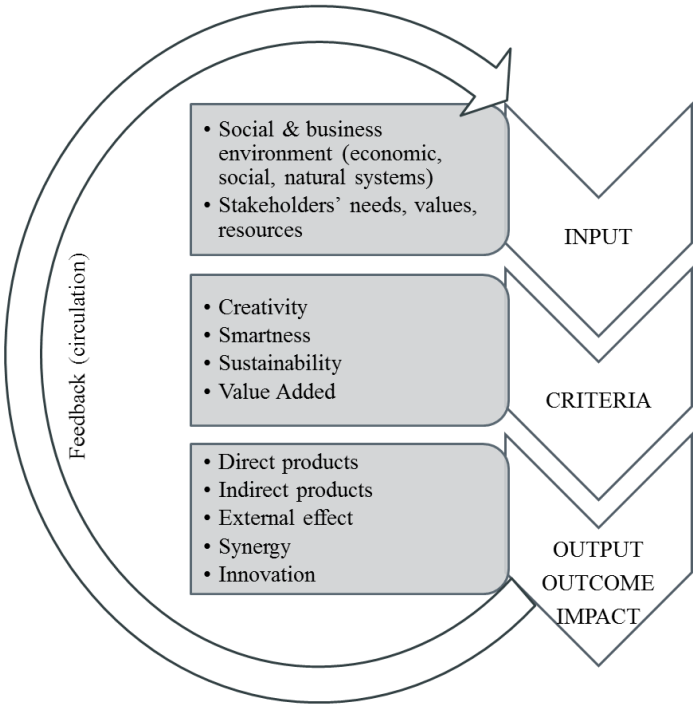


Figure 2. Framework of investment planning and evaluation in new paradigm – operational level, source: Author's own work

resilience against different threats (social, economic, ecological, etc.). But: *How can we compare benefits produced by buildings (...) with costs associated to negative changes in urban landscape? (...) Can economic evaluation of urban landscape balance the economic impact of its transformation?* (Girard, 2010, p. 307). The win-win composition of economic, ecological and social objectives requires evaluation which goes beyond economic and financial goals, and embraces both *hard* and *soft* values. Evaluation must then go beyond the output, but should anticipate, interpret and compare the quantitative and qualitative impact of the investment project and be a tool of coordinating choices of stakeholders on the basis of comparison between all costs and all benefits. The starting point of investment projects evaluation is then to precisely and comprehensively identify the stakeholders and net benefits considered in relation to economic, social and environmental criteria. According to P. Hardi and A. Martinuzzi (2007) sustainable development evaluation should also consider non-monetary and qualitative aspects, intervention and system reactions (here: outcome and impact), long-term risks, system dynamics. They argued that evaluation is a mutual learning process (here: feedback/circulation) and sustainable development evaluation constitute a basic factor for innovations. Finally, the authors claimed stakeholders' involvement in the evaluation (here: stakeholders' needs, values, resources).

The proposed conceptual strategic approach to the investment decision making rationality in urban development, can be operationalized through investment projects being planned and evaluated. Figure 2 illustrates the framework of investment planning and evaluation in new paradigm.

## 5. Summary

Despite the fact that city management can utilise the expertise of business studies, especially in terms of investment projects, cities cannot be run as a pure business. Local governments and enterprises operate in the same environment, with the same strategic aim – to increase competitiveness by development and creation of value added, but the understanding of these issues is different. Still, the understandable differences between the sectors cannot be an argument for the resignation of a systematic approach to evaluation of results of allocated resources. It is about adapting methods, concepts which are commonly used in the private sector. A sign of the achievements of business management in public sector is *New Public Management.* However, NPM subordinates the actions of the administration to the needs of the users of its services, and therefore may weaken the accountability to citizens. In the conditions of limited resources, NPM may result in a reduction of functions to those which are used the most often. Finally, the idea of maximum use of market mechanisms may lead to inconsistency with social and *soft* values – those which the market can hardly price in a true way. Therefore, public sector investment management should be based not only on outcome as assumed in NPM, but should also consider the process. Moving beyond NPM is then required. New Public Service (NPS) (Denhardt, Denhardt, 2011) is also an example of emerging approach, however it concen-

trates more on the general management than investment management.

A new approach to management of city investments, as developed and proposed in this research, is needed. It has been be established including the principles of sustainable smart development, triad *of creativity – circularisation – synergy*, stakeholder theory, and the idea of social-business responsibility. The approach primarily elevates the concept of the *public governance* which is characterised by a decentralisation, participation, constructivist and a win-win approach. These attributes increasingly refer to the decision-making process and subsequent implementation. Concerning decision making process relating investment, multi-criteria methods are recommended, as quantitative CBA is unable to encompass non-monetary values. The multi-criteria methods derive from logic and mathematics, and take into consideration diverse values and perspective of diverse actors as well. This means that the problem is not the absence of methods (Górecka, 2010), but the choice of a proper understandable method and building a hierarchy embracing the main goal and criteria (or sub criteria), and possible options.

The presented paradigm of principles of investment decision making rationality in urban development is also driven by the fact, that the investment in urban development are of *cross* nature – both business and public like. The typical investment classification which identifies public and private investment is not more sufficient. There may be social investments with commercial aspects and commercial investment with social aspects, and therefore the problem regarding planning and evaluation arises. Subsequently, it requires social-business responsibility and multi-criteria analysis, as explained above.

In the course of the literature analysis it was also found out that the traditional infrastructure investment classification of economic (technical) and social infrastructure is not sufficient and does not reflects reality. Several facts and observations: the interpenetration of public and business sector in terms of knowledge and investment, public sector's role of value protector (guarantor), and context of sustainability in terms of different infrastructure types, are reasons to identify group of investment relating infrastructure of business environment. That type of infrastructure is important also in terms of smart development.

The research fills the gap in existing theory relating investment decisions in urban development. The proposed approach proves its value added as it organizes a number of relevant content however it is just a proposition in the discussion relating to improvement of comprehensive strategic and operational approach to creating local investment development. The novelty of the approach relies more on a new application of current state-of-art than on inventing new ideas from the scratch as the general idea behind this research was to bring different concepts together to make a breakthrough in urban investment development methodology and implementation in order to support cities on strategic and operational level.

## References


1. ALFORD J., 2001, The implications of 'publicness' for strategic management theory, in: *Exploring Public Sector Strategy*, eds. Johnson G., Scholes K., Prentice Hall-Pearson Education, London, p. 1-16.
2. ANDRISANI P. J., HAKIM S., SAVAS E. S., 2002, *The New Public Management, Lessons from Innovating Governors and Mayors*, Kluwer Academic Publishers, Norwell.
3. APPLEBY P. H., 1949, *Policy and Administration*, University of Alabama Press, Chicago.
4. ATKINSON A. B., STIGLITZ J. E., 1980, *Lectures in Public Economics*, McGraw-Hill Book Co, Ltd., New York.
5. BARON M., 2012, Do We Need Smart Cities for Resilience, in: J*ournal of Economics & Management*, vol. 10, p. 32-46.
6. BEHRENS W., HAWRANEK P. M., 1991, *Manual for the preparation of industrial feasibility studies*, United Nations Industrial Development Organisation (UNIDO), Vienna.
7. BLOESCH J., von HAUFF M., MAINZER K., MOHAN S. V., RENN O., RISSE V., SONG Y., TAKEUCHI K., WILDERER P. A., 2015, Sustainable Development integrated in the Concept of Resilience, in: *Problemy Ekorozwoju/ Problems of Sustainable Development*, vol. 10, no 1, p. 7-14.
8. BOARDMAN A. E., GREENBERHG D. H., 2001, *Cost-Benefit Analysis. Concepts and Practice*, Prentice Hall, New Jersey.
9. BOUCKAERT G., 1993, Measurement and Meaningful Management, in: *Public Productivity & Management Review*, vol. 17, no 1, p. 31-43.
10. BOX R. C., MARSHALL G. S., REED B. J., REED C. M., 2001, New Public Management and Substantive Democracy, in: *Public Administration Review*, vol. 61, p. 608-619.
11. BRYSON J. M., CROSBY B. C., BLOOMBERG L., 2014, Public Value Governance: Moving Beyond Traditional Public Administration and the New Public Management, in: *Public Administration Review*, vol. 74, p. 445-456.
12. BOLAND T., FOWLER A., 2000, A systems perspective of performance management in public sector organisation, in: *The International Journal of Public Sector Management*, vol. 13, no 5, p. 417-446.
13. CHAN Y.-C. L, 1999, Performance measurement and adoption of balanced scorecard: A survey of municipal governments in the USA and

Canada, in: *The International Journal of Public Sector Management*, vol. 17, no 3, p. 204-221.
14. Commission of the European Communities, 2001, *Green Paper, Promoting a European Framework for Corporate Social Responsibility*, European Commission, Brussels.
15. DENHARDT J.V., DENHARDT R.B., 2011, *The New Public Service: Serving, Not Steering*, M. E. Sharpe, Armonk, New York.
16. DIXON M. J., 2012, *How Smart Cities Save Money (and the Planet)*, Harvard Business Review, HBR Blog Network, 29 Oct, https://hbr.org/2012/10/tech-savvy-cities-are-saving-m (20.09.2015).
17. DRUCKER P. F., 1973, Managing the Public Service Institution, The Public Interest, in: *College and Research Libraries*, vol. 37, no 1, p. 4-14.
18. European Commission, 2005, *Partnership Development Toolkit, A partnership oriented planning, monitoring and evaluation guide for facilitators of EQUAL Development and Transnational Partnerships*, Belgium http://ec.europa.eu/employment_social/equal_consolidated/data/document/pdtoolkit_en.pdf (10.09.2015).
19. EUROSTAT, 2015, *Sustainable development in the European Union, 2015 monitoring report of the EU Sustainable Development Strategy*, http://ec.europa.eu/eurostat/documents/3217494/6975281/KS-GT-15-001-EN-N.pdf (20.09.2015).
20. FISHER T., 2014, Public Value and the Integrative Mind: How Multiple Sectors Can Collaborate in City Building, in: *Public Administration Review*, vol. 74, p. 457-464.
21. FLINT J., RACO M., Introduction: Characterising the 'new' politics of sustainability: from managing growth to coping with crisis, in: *The Future of Sustainable Cities*: *Critical Reflections*, eds. Flint J., Raco M., University Press Scholarship, Southampton, 2012, p. 3-28.
22. FONTAINE C., HAARMAN A., SCHMID S., 2006, *The Stakeholder Theory*, Edlays.
23. FREEMAN R. E., 1984, *Strategic Management: a Stakeholder Approach*, Basic Books, Cambridge University Press, New York.
24. GEDDES P., 1915, *Cities in evolution: an introduction to the town planning movement and to the study of civics*, Williams & Norgate, London 1915.
25. GIFFINGER R., FERTNER C., KRAMAR H., KALASEK R., PICHLER-MILANOVIC N., 2007, MEIJERS E., *Smart Cities – Ranking of European Medium-Sized Cities*, Research Report, Vienna University of Technology, Vienna.
26. GIRARD L. F., 2011, Multidimensional Evaluation Processes to Manage Creative, Resilient and Sustainable City, in: *Aestimum*, vol. 59, p. 123-139.
27. GIRARD L. F., 2013, Toward a smart sustainable development of port cities/areas: the role of the 'historic urban landscape approach', in: *Sustainability*, vol. 5, no 10, p. 4329-4348.
28. GIRARD L. F., 2010, Creative Evaluations for a Human Sustainable Planning, in: *Making Strategies in Spatial Planning*, CERRETA M., CONCILIO G., MONNO V. (eds.), 2010, Springer, Dordrecht, Heidelberg, London, New York, p. 305-328.
29. GIRARD L. F., NIJKAMP P., 1997, *Le Valutazioni Integrate per lo Sviluppo Sostenibile della Città e del Territorio*, FrancoAngeli, Milano.
30. GÓRECKA D., 2010, On the choice of method in multi-criteria decision aiding process concerning European projects, in: *Multiple Criteria Decision Making '10-11*, eds. Trzaskalik T., Wachowicz T., University of Economics in Katowice, Katowice, p. 81-103.
31. GRIFFIN R. W., 2002, *Fundamentals of Management*, A&M University, Texas.
32. HALACHMI A., 1996, Business process reengineering in the public sector: Trying to get another frog to fly? In: *National Productivity Review*, vol. 15, no 3, p. 9-18.
33. HARDI P., MERTINUZZI A., 2007, Series editors' preface: Evaluating Sustainable Development – topics, trends and target groups of this new book series, in: *Sustainable Development in Europe. Concepts, Evaluation and Applications*, eds. Schubert U., Störmer E., Elgar E., Cheltenham, p. XVII-XXIV.
34. HIRIGOYEN G., LAOUER R., 2013, Convergence of Corporate and Public Governance: Insights From Board Process View, in: *SAGE Open*, April-June, p. 1-8.
35. HM Treasury, 2012, *A new approach to public private partnerships*, https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/205112/pf2_infrastructure_new_approach_to_public_private_parnerships_051212.pdf (2016.04.10).
36. HOLLANDS R., 2008, Will the Real Smart City Stand Up? Creative, Progressive, or Just Entrepreneurial? In: *City*, vol. 12, no 3, p. 302-320.
37. HOOD C., 1991, A public management for all seasons? In: *Public Administration*, vol. 69, p. 3-19.
38. ITU (International Telecommunication Union), 2014, *Smart sustainable cities: An analysis of definitions*, *Focus Group Technical Report*, http://www.itu.int/en/ITU-T/focusgroups/ssc/Documents/Approved_Deliverables/TR-Overview-SSC.docx (20.09.2015)
39. JONES P. S., 2003, Urban Regeneration's Poisoned Chalice: Is There an Impasse in (Community) Participation-based Policy? In: *Urban Studies*, vol. 40, no 3, p. 581-601.
40. KAGANOVA O. , 2011, *Guidebook on Capital Investment Planning for Local Governments*, The World Bank, http://siteresources.worldbank.org/INTURBANDEVELOPMENT/Resource

s/336387-1169585750379/UDS13CIP.pdf (10.09.2015).
41. KALAMBOKIDIS L., 2014, Creating Public Value with Tax and Spending Policies: The View from Public Economics, in: *Public Administration Review*, vol. 74, p. 519-526.
42. LEŹNICKI M., LEWANDOWSKA A., 2016, Contemporary Concepts of a City in the Context of Sustainable Development: Perspective of Humanities and Natural Sciences, *Problemy Ekorozwoju/ Problems of Sustainable Development*, vol. 11, no 2, 45-54.
43. LOMBARDI P., GIORDANO S., CARAGLUI A., DEL BO C., DEAKIN M. , NJIKAMP P., KOURTIT K. , 2011, *An advanced triple helix network model for smart city performance, Research Memorandum*, University of Amsterdam vol. 45, http://degree.ubvu.vu.nl/repec/vua/wpaper/pdf/20110045.pdf (20.09.2015).
44. LYONS M., SMUTS C., STEPHENS A., 2001, Participation, Empowerment and Sustainability: (How) Do the Links Work? In: *Urban Studies*, vol. 38, no 8, p. 1233– 1251.
45. MINISTRY of Economy, 2012, *Poland 2012 Report Economy*, Warsaw, https://www.mr.gov.pl/media/15367/Poland_2012_Report_economy_eng.pdf (10.09.2015).
46. MITCHELL R. K., AGLE B. R., WOOD D. J., 1997, Toward a Theory of Stakeholder Identification and Salience: Defining the Principle of Who and What Really Counts, in: *The Academy of Management Review*, vol. 22, no 4, p. 853-886.
47. NIJAKI L. K, WORREL G., 2012, Procurement for sustainable local economic development, in: *International Journal of Public Sector Management*, vol. 25, no 2, p. 133-153.
48. OSBORNE S. P., 2010, *The New Public Governance? Emerging Perspectives on the Theory and Practice of Public Governance*, Routledge, New York.
49. PAWŁOWSKI A., 2008, How many dimensions does sustainable development have?, in: *Sustainable Development*, vol. 16, no 2, p. 81-92.
50. PHELPS A., 2010, Rationale, practice and outcomes in municipal property asset management, in: *Journal of Corporate Real Estate*, vol. 12, no 3, p. 157-174.
51. POISTERT H., STREIB G. D., 1999, Strategic Management in the Public Sector: Concepts, Models, and Processes, in: *Public Productivity and Management Review*, vol. 22, no 3, p. 308-325.
52. RADNOR Z., OSBORNE S. P., 2013, Lean: A failed theory for public services?, in: *Public Management Review*, vol. 15, no 2, p. 265-287.
53. RAVETZ J., 2011, Urban Synergy-Foresight, Urban Governance in the EU, in: *Current Challenges and Future Prospects*, EU, p. 31-44.
54. ROBBINS S. P., DECENZO D. A., 2005, *Fundamentals of Management*, Pearson Education, New Delhi.
55. SAYCE S., SMITH J., COOPER R., VENMORE-ROWLAND P., 2006, *Real Estate Appraisal: From Value to Worth*, Blackwell Publishing Ltd., Oxford.
56. SIENKIEWICZ M. W., 2013, Determinants and effects on strategic management in the local government in Poland and western Europe, in: *Proceedings: NISPAcee Annual Conference Regionalization and Inter-regional Cooperation*, Belgrade, Serbia, May 16-18, p. 1-16.
57. SIMMIE J., MARTIN R., 2010, The Economic Resilience of Regions: Towards an Evolutionary Approach, in: *Cambridge Journal of Regions, Economy and Society*, vol. 3, p. 27-3.
58. SIMONE H. A., 1946, The Proverbs of Administration, in: *Public Administration Review*, vol. 6, no 1, p. 53-67.
59. STAMP J. C., 1923, The Contrast Between the Administration of Business and Public Affairs, in: *Public Administration*, vol. 1, p. 158-171.
60. STOKER G., 2006, Public Value Management: A New Narrative for Networked Governance?, in: *American Review of Public Administration*, vol. 36, no 1, p. 41–57.
61. UNITED NATIONS, Department of Economic and Social Affairs, Population Division, 2014(a), *World Urbanization Prospects: The 2014 Revision, Highlights*, New York.
62. UNITED NATIONS, General Assembly, 2014 (b), *Open Working Group of the General Assembly on Sustainable Development Goals, Open Working Group proposal for Sustainable Development Goals*, A/68/970, http://www.un.org/ga/search/view_doc.asp?symbol=A/68/970&Lang=E (20.09.2015).
63. WCED (Brundtland Commission), 1987, Our Common Future, Oxford University Press, Oxford.
64. WĘGRZYN J., 2016, The Perception of Critical Success Factors for PPP Projects in Different Stakeholder Groups, in: *Entrepreneurial Business and Economics Review*, vol. 4, no 2, p. 81-92.
65. WHITE A. D., 2011, A review of UK public sector real estate asset management, in: *Journal of Corporate Real Estate*, vol. 13, no 1, p. 6-15.
66. WOJEWNIK-FILIPKOWSKA A., 2012, Investments in the process of urban regeneration – concept of investment economic evaluation, in: J*ournal of the Polish Real Estate Scientific Society*, vol. 20, no 3, p. 247-259.
67. WOJEWNIK-FILIPKOWSKA A., RYMARZAK K M., 2013, Decision-making in corporate and municipal asset management – literature review, in: *International Journal of Real Estate Studies*, vol. 8, no 1, p. 16-29.

68. WOJEWNIK-FILIPKOWSKA A., RYMARZAK M., LAUSBERG C., 2015, Current Managerial Topics in Public Real Estate Asset Management, in: *World of Real Estate*, vol. 4, no 94, p. 5-10.
69. YANG K., 2007, Making performance measurement relevant? Administrators' attitudes and structural orientations, in: *Public Administration Quarterly*, vol. 31, no 3, p. 342-383.
70. ZEEMERING E., 2009, What does sustainability mean to city officials?, in: *Urban Affairs Review*, vol. 45, p. 247-73.
71. ZELENY M., 2010, Knowledge Management and Strategic Self-Sustainability: A Human Systems Perspective, in: eds. Cerreta M., Concilio G., Monno V., *Making Strategies in Spatial Planning*, Springer Dordrecht Heidelberg London New York, p. 257-280.

**PROBLEMY EKOROZWOJU – PROBLEMS OF SUSTAINABLE DEVELOPMENT**
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# Effect of Drilling for Shale Gas on the Quality of Atmospheric Air

# Wpływ prac wiertniczych prowadzonych za gazem ziemnym w łupkach na jakość powietrza atmosferycznego

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## Abstract
Shale gas is an alternative for conventional energy sources. When extracted in compliance with environmental and sustained development rules, it favors the concept of diversification of energy sources, giving spur to the development of economy and technology, and before all, to the energy safety of the country.
Poland is among countries, where expectations regarding shale gas are very high. Most of the exploration works for shale gas there are performed with the use of rigs, whose subassemblies are driven by electrical motors powered by mobile generators driven by diesel engines. The number of aggregates and their total power are selected each time on the basis of power balance of particular technological subassemblies and the emergency generation system. Diesel combustion motors used for powering generators are the only source of dust and gaseous emissions to the air. A mobile technological boiler room fed with oil is another source of emissions in the winter period. For the purpose of evaluating impact of rigs on the air environment in the course of prospecting for shale gas an emission model was worked out with five emission points. Four sources were connected with the operation of combustion motors (each 1257 kW) powering generators, and the fifth one (375 kW) feeding technological boiler room. The results of the tests on the environmental impact on motors and boiler room used during shale gas prospecting on the quality of air have been presented in the paper. The tests were performed with the use of mathematical modeling employing real technological data from existing installations.

**Key words:** drilling works, shales, shale gas, air quality, emission of pollutants, dust and gaseous pollutants, contamination of air, mathematical modeling

## Streszczenie
Gaz z formacji łupkowych stanowi alternatywę dla konwencjonalnych źródeł energii. Wydobywany z poszanowaniem wymogów ochrony środowiska oraz w zgodzie z regułami zrównoważonego rozwoju jest elementem bezpieczeństwa energetycznego państwa, wpisuje się w logikę dywersyfikacji źródeł energii oraz stanowi impuls do rozwoju gospodarczego i naukowo-technicznego kraju.
Polska należy do krajów, w których z gazem łupkowym wiąże się duże nadzieje. Tutaj proces wiercenia otworów poszukiwawczych za gazem ziemnych w skałach łupkowych w większości przypadków prowadzony jest przy wykorzystaniu urządzeń wiertniczych, w których poszczególne podzespoły napędzane są silnikami elektrycznymi.

Jednak źródłem energii elektrycznej są dla nich mobilne zestawy generatorów napędzane silnikami wysokoprężnymi dużej mocy. Ilość agregatów oraz ich sumaryczna moc dobierana jest każdorazowo w oparciu o wykonany bilans mocy poszczególnych podzespołów technologicznych i systemu zasilania awaryjnego.
Wysokoprężne silniki spalinowe dużej mocy, wykorzystywane do napędu generatorów prądu, stanowią istotne źródło emisji zanieczyszczeń pyłowo-gazowych do powietrza. Ponadto w okresie zimowym dodatkowym źródłem emisji do powietrza jest mobilna kontenerowa kotłownia technologiczna zasilana olejem opałowym.
Dla potrzeb oceny wpływu pracujących urządzeń wiertniczych na jakość powietrza w trakcie prowadzenia prac poszukiwawczych za gazem ziemnym w skałach łupkowych, w stworzonym modelu emisyjnym założono pracę 5 punktowych źródeł emisji zorganizowanej. Cztery źródła są związane z pracą silników spalinowych, każdy o mocy 1257 kW, napędzających generatory, a piąty z pracą kotłowni technologicznej o mocy 375 kW.
W artykule przedstawiono wyniki badań wpływu na jakość powietrza silników spalinowych oraz kotłowni wykorzystywanych przy realizacji prac wiertniczych związanych z poszukiwaniem gazu ziemnego w skałach łupkowych. Badania prowadzone były metodą modelowania matematycznego w oparciu o rzeczywiste dane technologiczne pochodzące z obszaru wierceń poszukiwawczych.

**Słowa kluczowe:** prace wiertnicze, łupki, gaz z łupków, jakość powietrza, emisja zanieczyszczeń, zanieczyszczenie pyłowe i gazowe, zanieczyszczenie powietrza, modelowanie matematyczne

## 1. Introduction

Sustainable development refers to fulfillment of basic human needs. Since our civilization could not survive without energy it is no wonder that in a report called *Our Common Future* (WCED, 1987) energy was included among essential issues of sustainability. Since resources of traditional fossil fuels are shrinking, looking for alternative sources of energy is a must.
One of the alternatives to conventional energy sources is shale gas (Michałowski et al., 2012).
In this paper we present Polish experience. This is one of the countries, where expectations regarding shale gas are very high. The truth is, that when shale gas is extracted in compliance with environmental and sustained development rules, it favors the concept of diversification of energy sources, giving spur to the development of economy and technology, and before all, to the energy safety of the country. Regarding sustainability we must think however not only about exploitation of shale gas, but also about the environmental effects of drilling.
Shale formations with adsorbed or free natural gas are characterized by very low permeability and porosity. Therefore the efficient production of gas in such conditions requires using many multilateral directional wells and extensive fracturing jobs.
The drilling of opening wells starts with vertical sections in the caprock. The, above the roof of the shale strata, they are given the form of directional wells and long horizontal sections (about 2 to 3 km long) are drilled. About 20 fracturing jobs are performed in these sections to obtain a hydraulic connection between the rock and the well. Specialist drilling tools are used for this purpose. They are powered by high-pressure diesel engines of total power reaching up to a few thousands kW. For the sake of limiting the negative influence of drilling works on the environment, especially on the ground surface, 6 to 8 vertical wells are frequently drilled from one rig area and then 4 to 6 horizontal sections from each of them.
The risk analysis of drilling works referred to in (Zawisza at al., 2007; Rahm at al., 2011) reveals that the operation of diesel engines and mobile boiler room has most biggest impact on the air around the rig in the course of opening up operations. They emit large quantities of dust-gaseous pollutions, e.g.: nitrogen dioxide ($NO_2$), sulfur dioxide ($SO_2$), carbon dioxide ($CO_2$), carbon oxide (CO), dust $PM_{10}$ and $PM_{2.5}$, ammonia, methane ($CH_4$), benzo(a)pyrene (b(a)p), benzene, toluene, xylene, formaldehyde, acetaldehyde, acrolein.
The results of analyses of the effect of a combustion engine and a mobile boiler room on the quality of atmospheric air during shale gas prospecting have been discussed in this paper. The research was conducted with the use of mathematical modeling method based on real technological data from the area of Gdańsk Pomerania.

## 2. Identification of sources of emissions to the air

In Poland the process of performing exploration wells for shale gas is conducted with the use of drilling tools, the subassemblies of which are fed by electrical engines. The sources of electrical energy are mobile generators powered by high power diesel engines. The number of generators and their total power are selected each time on the basis of balance of power of particular technological subassemblies and the emergency generation system.
The high power diesel engines used for driving generators are a significant source of dust-gaseous atmospheric emissions (Macuda, Konieczyńska, 2015). A mobile technological boiler room fed by fuel oil is another source of contamination in winter period. Owing to the high consumption of both diesel and fuel oil, they have to be stored in relatively capacious tanks in the rig area. These tanks can be another source of hydrocarbon emissions which can take place at the stage of reloading (huge tank breathing), storage (small tank breathing due to tempera-

Table 1. List of emission indices for engines over 560 kW fed with diesel oil (U.S. EPA, 2013)

| Pollutant | Method of limiting emission | Fuel – diesel oil | | |
|---|---|---|---|---|
| | | Emission index referred to engine power (on output) | Emission index referred to energy introduced to engine with fuel [a] | Quality of emission index [b] |
| | | [g/kWh] | [ng/J] | |
| $NO_x$ | No | 14.592 | 1376 | B |
| | Delayed fuel injection | 7.904 | 817 | B |
| CO | No | 3.344 | 365.5 | C |
| $SO_x$ [c] | No | 4.918 · S | 434.300 · S | B |
| $CO_2$ [d] | No | 705.280 | 70950 | B |
| PM | Delayed fuel injection | 0.426 | 43.0 | B |
| TOC (as $CH_4$) | No | 0.429 | 38.7 | C |
| Methane | No | [e] | [e] | E |
| NMVOC | No | [e] | [e] | E |

[a] Indices calculated for engine powered by diesel oil of calorific value equal to 44 900 kJ/kg and density: 850.767 kg/m$^3$.
[b] Quality of evaluation of emission index according to the scale: A - perfect, B – above average, C - average, D – below average, E - poor, F – no evaluation (no documented analyses).
[c] Index calculated for maximum sulfur content in diesel oil S [%].
[d] Assumed 100% conversion of C in fuel to $CO_2$.
[e] The analyses performed on only one engine revealed that the total organic carbon (TOC) measured in exhaust gases is based on methane in 9% and on non-methane volatile organic compounds (NMVOC) in 91%.

ture and pressure) and also during leaks of the fuel supply systems. The magnitude of the hydrocarbon emission from the tank is very low due to the low pressure of volatile vapor compounds of diesel and fuel oils. Therefore this emission was ignored in further analyses as negligible.

For the sake of analyzing the impact of operating rig on the quality of air during shale gas prospecting jobs, the emission model was equipped with 5 sources of emission (organized and point), associated with:

- emitters no. 1 – 4, emission from 4 combustion engines, each 1257 kW, driving generators,
- emitter no. 5 – emission from technological boiler room, 375 kW.

## 3. Quantitative calculation of emissions to the atmosphere

Emissions of dust and gases to the atmosphere in the rig area while drilling the vertical wellbore section and its horizontal off-springs are connected with the operation of diesel engines driving generators and a technological boiler room. This situation was accounted for in the model where the operation of 4 generators and a boiler room was assumed.

### *3.1. Dust and gas emission from diesel engines powering generators*

The calculations of the emission of dust and gaseous substances from diesel engines powering the generators were performed on the example of a motor CATERPILLAR 3512B. This engine is most frequently applied for powering mobile generators which are used in drilling industry. It has the following parameters (Caterpillar oil&gas, 2013): electric power: 1207 kW (1508 kVA), mechanical power: 1257 kW (1687 KM), fuel: diesel oil, cylinders: 12, constant number of rotations1500 rpm, standard emission: U.S. EPA Tier 2, fuel consumption at 100% load: 293 dm$^3$/h, 75%: 226 dm$^3$/h, 50%: 159 dm$^3$/h, temperature of exhaust gases at 100% load: 382 $^o$C, 75%: 374 $^o$C, 50%: 375 $^o$C, exhaust gases flow rate at 100% load: 251 m$^3$/min, 75%: 205 m$^3$/min, 50%: 154 m$^3$/min. It was assumed in the calculations that all 4 engines were of the same type.

When evaluating the atmospheric emission from diesel engines supplied by aggregates the following parameters were also taken into consideration: type and power of engine, type of substitute fuel, work characteristic (constant-speed, variable-speed), fuel consumption, treatment and emission-reduction systems, compliance to the emission standard. The US Environmental Protection Agency (U.S. EPA) in its document AP-42 (U.S. EPA, 2013) and the European Environment Agency (EEA) list emissions of substances introduced to the atmosphere by the analyzed engines in a database worked out within the project EMEP/CORINAIR (EEA, 2016) . Table lists emission indices quoted after AP-42 (U.S. EPA) (U.S. EPA, 2013), which refer to engines of power over 560 kW, i.e. the ones described in the calculation example.

The analysis of table 1 reveals that the index of $SO_2$ emission depends on the percentage of sulfur (S) in the combusted fuel. According to the standard PN-EN 590 the sulfur content in diesel oil in Poland cannot exceed 0.001 wt.% (Polish Committee for Standardization, 2013).

A diesel engine emits aerosols of different chemical composition to the atmosphere. A qualitative and quantitative list of indices of aerosol emissions from a diesel engine (> 560 kW) with no emission-reduction system has been presented in table 2.

Table 2. Aerosol emitted by stationary diesel engine of over 560 kW, with no emission reduction system provided (U.S. EPA, 2013)

| Contaminants | Emission index referred to energy introduced to engine with fuel [ng/J] |
|---|---|
| Fractions of analyzed solid particles [a)]: | |
| < 1μm | 20.554 |
| < 3μm | 20.597 |
| < 10μm | 21.328 |
| Total amount of analyzed solid particles | 26.66 |
| Condensed liquid particles | 3.311 |
| $PM_{10}$ [b)] | 24.639 |
| Total dust [c)] | 29.971 |

a) The fractions interval is expressed as aerodynamic diameters of particles.
b) Sum of total measured dust particles of aerodynamic diameters < 10 μm and liquid condensed particles in the same fraction interval.
c) Sum of total measured dust particles and liquid condensed particles.

A diesel engine also emits volatile organic compounds (VOC) and polycyclic aromatic hydrocarbons (PAH). The emission indices for selected groups of compounds have been presented in tables 3 and 4, respectively.

Table 3. Emission indices of selected volatile organic compounds from stationary diesel engine (over 560 kW), with no emission reduction system provided (U.S. EPA, 2013)

| Contaminants | Emission index referred to energy introduced to engine with fuel [ng/J] |
|---|---|
| Benzene | 0.33368 |
| Toluene | 0.12083 |
| Xylene | 0.08299 |
| Propylene | 1.19970 |
| Formaldehyde | 0.03393 |
| Acetaldehyde | 0.01084 |
| Acrolein | 0.00339 |

When the engine is not equipped with any emission-reduction system, the indices listed in tables 1-4 should be used in predictions. The amount of the emission can be calculated on the basis of the power of engine in kW or amount and kind of fuel combusted in an hour. When the engine is equipped with treatment systems, the emission value should be corrected by the reduction degree obtained with a given treatment technique. The emission generated by engines, meeting certain emission limits, should be calculated with the use of boundary emission values presented in table 5.

Table 4. Emission indices of selected polycyclic aromatic hydrocarbons from stationary diesel engine (over 560 kW), with no emission reduction system provided (U.S. EPA, 2013)

| Contaminants | Emission index referred to energy introduced to engine with fuel [ng/J] |
|---|---|
| Naphthalene | 5.59E-02 |
| Acenaphthalene | 3.97E-03 |
| Acenaphthene | 2.01E-03 |
| Fluorene | 5.50E-03 |
| Phenanthrene | 1.75E-02 |
| Anthracene | 5.29E-04 |
| Fluorantene | 1.73E-03 |
| Pyrene | 1.60E-03 |
| Benzo(a)anthracene | 2.67E-04 |
| Chrysene | 6.58E-04 |
| Benzo(b)fluorantene | 4.77E-04 |
| Benzo(k)fluorantene | 9.37E-05 |
| Benzo(a)pyrene | 1.11E-04 |
| (Indeno(1,2,3-cd)Pyrene | 1.78E-04 |
| Dibenz(a,h)anthracene | 1.49E-04 |
| Benzo(g,h,l)perylene | 2.39E-04 |
| Total PAH | 9.12E-02 |

In the case of the analyzed type of engine, the following values should be accounted for in the emission calculations:

- for such contaminants as: carbon oxide (CO) and fine dust > 10 μm of grain size (PM10)
- from emission limits of U.S. EPA Tier 2 adequate to a diesel engine of power exceeding 560 kW (table 5),
- for hydrocarbons: from EPA guidelines AP-42 containing emission indices referred to the quantity of energy provided to an engine in fuel (tables 3 and 4),
- for nitrogen oxides ($NO_x$) – from EPA guidelines AP-42 containing emission indices referred to the power of engine (table 1),
- for carbon dioxide ($SO_2$) – from EPA guidelines AP-42 containing emission indices referred to the energy provided to the engine in fuel (table 1).

The calculation of hydrocarbon and sulfur dioxide emission based on emission indices referred to the amount of energy provided to the engine in fuel was performed for calorific value of diesel oil equal to 42.5 MJ/kg and density equal to 0.83 kg/dm$^3$. In each case the calculations were performed for an engine loaded in 100%. For thus formulated assumptions and combustion of 293 dm$^3$/h of diesel oil, the energy provided to the engine within 1 hr of its operation was calculated: 10 335.58 MJ/h. Knowing the energy provided to the engine with fuel, the hourly emissions of selected specific hydrocarbons, including polycyclic aromatic hydrocarbons (PAH), could be calculated. Their values have been given in tables 3 and 4. Then the annual emission of the analyzed hydrocarbons was calculated, assuming the duration of drilling vertical and horizontal sections on the

Table 5. Emission limits for diesel engines > 560 kW used, e.g. in pump aggregates (Dieselnet, 2016)

| Contaminant | Emission limits in g/kWh | | | |
|---|---|---|---|---|
| | Tier 1 | Tier 2 | Tier 4 Interim | Tier 4 |
| | 2000-2005 | 2006-2010 | 2011-2014 | +2015 |
| CO | 11.4 | 3.5 | 3.5 | 3.5 |
| HC | 1.3 | - | 0.4 | 0.19 |
| NMHC+$NO_x$ | - | 6.4 | - | - |
| $NO_x$ | 9.2 | - | 0.67 | 0.67 |
| PM | 0.54 | 0.2 | 0.1 | 0.04 |

Table 6. Emission of selected VOC emitted to air from engine powering generator

| Contaminant | Emission [kg/h] | Emission [kg/year] |
|---|---|---|
| Benzene | 0.00345 | 4.966 |
| Toluene | 0.00125 | 1.798 |
| Xylene | 0.000858 | 1.235 |
| Propylene | 0.01240 | 17.855 |
| Formaldehyde | 0.000351 | 0.505 |
| Acetaldehyde | 0.000112 | 0.161 |
| Acrolein | 0.000035 | 0.0504 |

Table 7. Hourly and annual emission of PAH emitted to air from engine powering the generator

| Contaminant | Emission [kg/h] | Emission [kg/year] |
|---|---|---|
| Naphthalene | 5.78E-04 | 0.83197 |
| Acenaphthalene | 4.10E-05 | 0.05907 |
| Acenaphthene | 2.08E-05 | 0.02995 |
| Fluorene | 5.69E-05 | 0.08192 |
| Fenantren | 1.81E-04 | 0.26111 |
| Anthracene | 5.47E-06 | 0.00787 |
| Fluorantene | 1.79E-05 | 0.02579 |
| Pyrene | 1.65E-05 | 0.02374 |
| Benzo(a)anthracene | 2.76E-06 | 0.00398 |
| Chrysene | 6.80E-06 | 0.00979 |
| Benzo(b)fluorantene | 4.93E-06 | 0.00710 |
| Benzo(k)fluorantene | 9.69E-07 | 0.00140 |
| Benzo(a)pyrene | 1.14E-06 | 0.00164 |
| Indeno(1,2,3-cd)pyrene | 1.84E-06 | 0.00265 |
| Dibenzo(a,h)anthracene | 1.54E-06 | 0.00221 |
| Benzo(g,h,l)perylene | 2.47E-06 | 0.00356 |
| **Total PAH** | **9.42E-04** | **1.35676** |

Table 8. Hourly and annual emission of $NO_x$, $SO_2$, CO, $PM_{10}$ and $PM_{2.5}$ to air from one engine powering the generator

| Contaminant | Emission [kg/h] | Emission [Mg/year] |
|---|---|---|
| $NO_x$ | 9.935 | 14.307 |
| $SO_2$ | 0.00449 | 0.00646 |
| CO | 4.400 | 6.335 |
| $PM_{10}$ | 0.251 | 0.362 |
| $PM_{2.5}$ | 0.226 | 0.326 |

level of 60 days/year, i.e. 1440 hrs/year. The 1-hr and annual emissions of these substances have been listed in tables 6 and 7.

The $SO_2$ emission was calculated with the index method on the basis of calculated energy which was provided to the engine in fuel. The respective emission index used in the calculations has been presented in table 1. The maximum possible sulfur content in fuel, which is available on the Polish market, equals to %S = 0.001% (Polish Committee for Standardization, 2013). A 1-hr emission of $NO_x$, CO and PM (all of the emission is dust $PM_{10}$) was calculated as a product of respective emission indices ($NO_x$ = 7.904 g/kWh, CO = 3.5 g/kWh, PM = 0.2 g/kWh) and power of engine (P = 1257 kW, at 100% load). For better illustration of the real noxiousness of the dust from the combustion motor an additional assumption was made that the dust emitted with exhaust gases contained 95% fractions of grain size < 2.5 μm ($PM_{2.5}$). The $NO_x$ emission was calculated thanks to the emission index, which assumed that the engine was equipped with a system of fuel injection delay and did not have any exhaust gas treatment mechanisms. The results of calculation of the hourly and average annual emission for the assumed time of work of the engine (t = 1440 h/year) have been listed in table 8.

In the calculation of contaminants propagation each of the four concurrently operating engines will be an individual source of emission, which will have its own allotted point emitter labeled with the successive number (1-4).

*3.2. Emission of dust and gaseous substances from the mobile Boiler room*

In colder months the rig can operate only when the rooms of the crew are heated and the technological installations are protected against freezing.

It was assumed in the paper that the rig would be equipped with a mobile boiler room having the following parameters: boiler capacity: 375 KW, fuel: light fuel oil, calorific value of fuel: 42.6 MJ/kg, density of fuel: 0.86 kg/dm$^3$, maximum sulfur content in fuel: 0.1%, energy efficiency of boiler: 90%, heat capacity: 1 350 MJ/h. The time of operation of the boiler room was assumed to be identical as the time of drilling vertical and horizontal section of the well, i.e. 60 days/year (1440 h/year). The least favorable emission variant was assumed, i.e. 100% load of the boiler room.

The calculation of suspended dust ($PM_{10}$), sulfur dioxide ($SO_2$), nitrogen oxides ($NO_X$ expressed as $NO_2$) and carbon oxide (CO) was based on emission indices presented in the guidelines of the Ministry of Environmental Protection, Natural Resources and Forestry of April 1996: Emission indices for contaminants introduced to the atmosphere from the combustion of fuels (Ministry of Environmental Protection, Natural Resources And Forestry, 1996). The emission indices of basic substances emitted in the process of fuel oil combustion, referred to the quantity of burned fuel in m$^3$, have been presented in table 9. The emission could be calculated on the basis of known hourly emission of fuel at 100% loading of the boiler room. This can be calculated from the formula:

$$\boldsymbol{B_{max}} = \frac{\boldsymbol{100 \cdot Q_{max}}}{\boldsymbol{W \cdot \eta \cdot \rho}} \quad (1)$$

where:

$B_{max}$ – maximum amount of combusted diesel oil at 100 % heat load of the boiler [dm$^3$/h],

$Q_{max}$ – maximum heat capacity at 100 % heat load of the boiler [kJ/h],

$W$ – calorific value of light diesel oil [kJ/h],

$\eta$ – energy efficiency of the boiler [%],

$\rho$ – density of light diesel oil [kg/dm$^3$].

Substituting values of particular entry data (already defined) authors could define the hourly consumption of light fuel oil on the level of 41 dm$^3$/h. Having known the hourly fuel consumption and emission indices of the analyzed substances, the hourly emission of these substances could be calculated. The yearly emission was calculated on the basis of hourly emission and the assumed time of operation of the boiler room (t = 1440 h/year). The calculated values have been presented in table 9.

For the sake of the modeling, the mobile boiler room was assumed to have a point emitter no. 5.

## 4. Calculation of dispersion in air – methodology and assumptions

The effect of shale gas prospecting on the quality of air was assessed with the use of the gaussian model of contaminants propagation in atmospheric air. In Poland this model is recommended for evaluating the influence of emissions from point emitters on the air quality in areas of non-complicated orography. The evaluation was performed only for contaminants which had the strongest influence on the air, and for which admissible concentrations have been established in the Polish regulations, i.e.: PM10, $PM_{2.5}$, $NO_2$, $SO_2$, CO and benzene. In this method the concentrations of the analyzed substances in air could undergo a comparative analysis with the admissible values. The remaining substances emitted to the air after the combustion of fuels in engines powering the generator and from the mobile boiler room, for which the emission values were established within the analyses, will not be taken into account because of their marginal impact on the concentration level.

The following calculations were performed within the modeling procedure: maximum concentrations averaged for 1-hr ($S_1$), respective percentiles from 1-hr concentrations during a year ($S_{99.8}$) corresponding to admissible frequency of exceeding 1-hr reference values in air or admissible levels of substances in air{$P(D_1)$}, average annual concentrations ($S_a$), dust precipitation on the ground surface ($O_p$).

The modeling was performed on the ground level (z = 0 m) in a regular grid of receivers localized at a distance of 50 m from one another. The calculation area had a square shape (1150 m side) and was defined in a local coordinates system. The rig was localized in the center of this area in the form of a square (150 m side). The analyzed sources of emissions were also placed in that area.

The assumed average coefficient of aerodynamic roughness of the surface for the assumed calculation area equaled to $z_o$ = 0.5 m. The calculations made use of a 12-sector wind rose defined by the meteorological station in Gdańsk (Fig. 1).

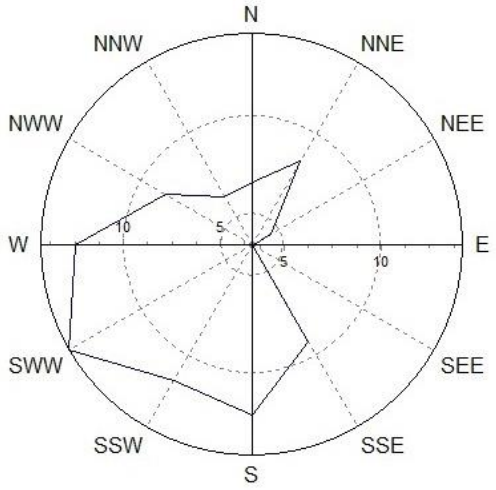


Figure 1. Annual wind rose plot for Gdańsk-Wrzeszcz

Table 9. Hourly and annual emission of $PM_{10}$, $PM_{2.5}$, $SO_2$, $NO_2$, CO, emitted to air from mobile boiler room

| Contaminant | Emission index | Emission | |
|---|---|---|---|
| | [kg/m$^3$] | [kg/h] | [kg/year] |
| PM10 | 1.8 | 0.0738 | 106.272 |
| $PM_{2.5}$* | 1.35 | 0.0554 | 79.704 |
| $SO_2$ | 1.9 | 0.0779 | 112.176 |
| $NO_2$ | 5 | 0.205 | 295.2 |
| CO | 0.6 | 0.0246 | 35.424 |
| * Emission index for $PM_{2.5}$ calculated on the assumption that dust particles of diameter < 2.5 μm constitute only 75% of particles $PM_{10}$ | | | |

Table 10. Coordinates of point emitters1-5, their geometric parameters and parameters of exhaust gases

| Emitter no. | Emitter | Emitter's coordinates | | Height of emitter | Diameter of emitter | Temp. of gases | Velocity of gases | $C_p$ |
|---|---|---|---|---|---|---|---|---|
| | | X [m] | Y [m] | [m] | [m] | [°C] | [m/s] | [kJ/m$^3$·K] |
| 1 | Generator no. 1 | 590 | 530 | 4.0 | 0.35 | 382 | 43.5 | 1.40 |
| 2 | Generator no. 2 | 590 | 525 | 4.0 | 0.35 | 382 | 43.5 | 1.40 |
| 3 | Generator no. 3 | 555 | 530 | 4.0 | 0.35 | 382 | 43.5 | 1.40 |
| 4 | Generator no. 4 | 555 | 525 | 4.0 | 0.35 | 382 | 43.5 | 1.40 |
| 5 | Mobile boiler room | 610 | 555 | 5.7 | 0.2 | 150 | 2.0 | 1.40 |

Table 11. Emission after 1hr from generators (emitters 1-4) and mobile boiler room (emitter 5)

| Substance | Generators (emitters 1-4) | Mobile boiler room (emitter 5) |
|---|---|---|
| | [kg/h] | [kg/h] |
| $NO_2$ | 9.93533 | 0.20500 |
| $SO_2$ | 0.00449 | 0.07790 |
| CO | 4.39950 | 0.02460 |
| $PM_{10}$ | 0.25140 | 0.07380 |
| $PM_{2.5}$ | 0.22626 | 0.05535 |
| Benzene | 0.003449 | - |
| Benzo(a)pyrene | 0.0000011 | - |

The assumed coordinates of emitters, their geometrical parameters (geometric height of the emitter and its outlet diameter), parameters of exhaust gases (temperature, velocity flow rate on the emitter's outlet, specific heat of gases at constant pressure) have been presented in table 10. The parameters of emitters and exhaust gases were defined on the basis of real parameters of devices most frequently used in rigs.

The assumed hourly emission from 4 generators and a mobile boiler room have been listed in table 11.

## 5. Evaluation of the effect of shale gas prospecting on air quality

The results of calculations on the propagation of pollution in the atmosphere have been interpreted in line with the *Regulation of the Environment Minister of 24 August 2012 about the level of some substances in air* (Environment Minister, 2012) and *Regulation of the Environment Minister of 26 Jan. 2010 about reference values for some substances in air* (Environment Minister, 2010).

The admissible levels and reference values for the analyzed substances in air have been listed in table 12.

The reference/admissible 1-hr concentrations of suspended dust $PM_{10}$ and $PM_{2.5}$, $NO_2$, CO, as well as benzene should not be exceeded more frequently than by 0.2% of the year, i.e. $D_1$ cannot exceed 99.8 percentile of 1-hr concentrations. In the case of 1-hr $SO_2$ concentrations the reference/admissible values cannot be exceeded more frequently than by 0.274% of the year (99.726 percentile of 1-hr concentrations).

The results of calculations of the analyzed substances in air, as referred to their reference/admissible values, have been listed in table 13.

All maximum 1-hr and maximum average annual concentrations were observed in one receptor of local coordinates X=600 m and Y=550 m and stayed within the rig area. From among the dust-gaseous substances emitted to the atmosphere only $NO_x$ emission, calculated for $NO_2$, constituted a serious source of emission. In the case of 1-hr concentrations in the rig area the maximum values can reach even 1854 μg/m$^3$ and the 99.8 percentile of these concentrations $P(D_1)$ can be exceeded. The admissible value is not expected to go beyond the average annual concentration ($D_a$). All calculated maximum concentrations listed in table 13 were observed in the most unfavorable dispersion conditions, i.e. at stable or slightly stable state of atmospheric equilibrium. The spatial distributions of 1-hr concentration, the frequency of exceeding it and average annual concentrations from four generators and a mobile boiler

Table 12. Admissible and reference levels of analyzed substances in air [μg/m$^3$]

| Contaminant | Validity | Admissible level after (Environment Minister, 2012) (reference value after (Environment Minister, 2010)) | |
|---|---|---|---|
| | | $D_1$ | $D_a$ |
| $PM_{10}$ | - | (280) | 40 (40) |
| $PM_{2.5}$ | from 1 Jan. 2015 to 31 Dec. 2019 | - | 25 (-) |
| | from 1.01.2020 | - | 20 (-) |
| $NO_2$ | - | 200 (200) | 40 (40) |
| $SO_2$ | - | 350 (350) | 20 (20) |
| CO | - | (30000) | - |
| Benzene | - | (30) | 5 (5) |

Table 13. Calculated maximum concentrations after 1-hr and maximum average annual concentrations in air caused by emissions from 4 generators and mobile boiler room

| Substance | Maximum concentration after 1-hr [μg/m$^3$] | | Maximum frequency of exceeding $D_1$ [%] | | Maximum average annual concentration [μg/m$^3$] | |
|---|---|---|---|---|---|---|
| | Calculated | % $D_1$ | Calculated | Admissible | Calculated | % $D_a$ |
| $PM_{10}$ | 24.6 | 8.8 | 0 | < 0.2 | 0.462 | 1.2 |
| $PM_{2.5}$ | 21.9 | - | 0 | < 0.2 | 0.404 | 1.6[1)] |
| $PM_{2.5}$ | 21.9 | - | - | - | 0.404 | 2.0[2)] |
| $NO_2$ | 1854 | 927.0 | **3.39** | < 0.2 | 31.022 | 77.6 |
| $SO_2$ | 9.1 | 2.6 | 0 | < 0.274 | 0.171 | 0.86 |
| CO | 820 | 2.7 | 0 | < 0.2 | 13.603 | - |
| Benzene | 0.64 | 2.1 | 0 | < 0.2 | 0.0106 | 0.21 |

1) % $D_a$ referred to admissible concentration $PM_{2.5}$ in air valid by 31 Dec. 2019
2) % $D_a$ referred to admissible concentration $PM_{2.5}$ in air valid from 1 Jan. 2020

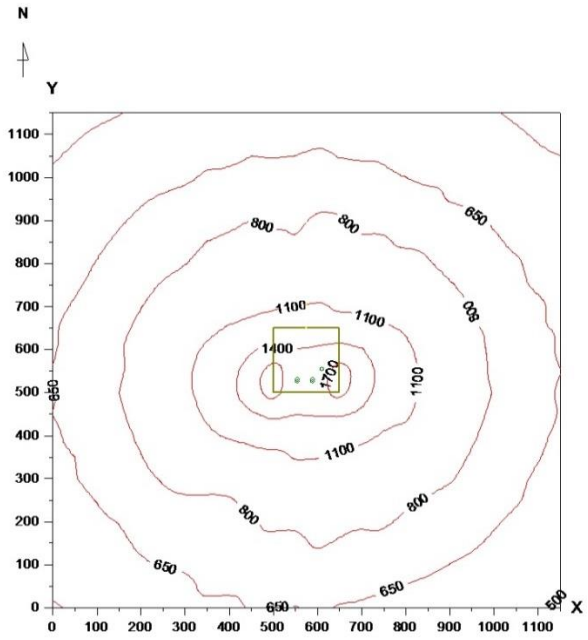


Figure 2. Spatial distribution of isolines of maximum concentrations after 1-hr presence of $NO_2$ in air

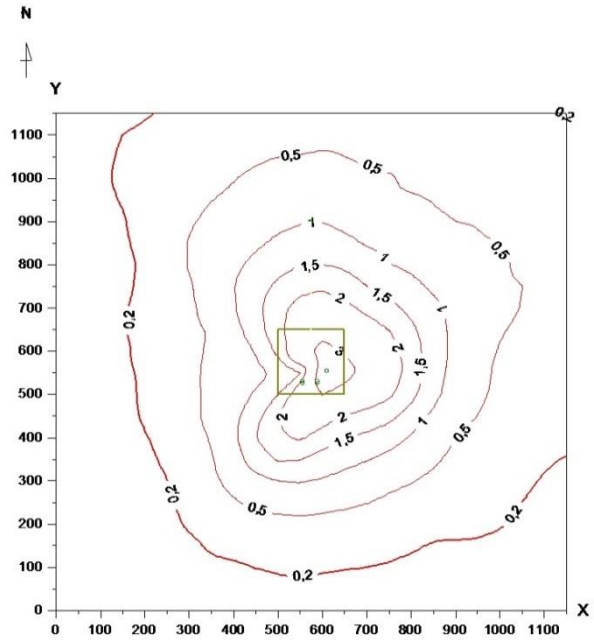


Figure 3. Spatial distribution of frequency of exceeding maximum concentrations after 1-hr presence of $NO_2$ in air

room working at maximum capacity have been presented in figs. 2-4. The rig area was marked as a square in the calculation center.

The analysis of table 13 and figures 2-4 shows that the substance which may contribute to the exceeding of admissible concentrations in air in the course of shale gas prospecting is $NO_2$, whose high 1-hr concentration may extend far away beyond the rig area and be noxious for the environment. The analysis of spatial distributions of isolines of maximum 1-hr and average annual concentrations of the remaining substances emitted from the analyzed sources revealed that in each case the concentrations of these substances will meet the standards for air beyond the rig area. The percentages of maximum 1-hr and average annual concentrations calculated for the most unfavorable emissions and meteorological conditions

equaled to 8.8 and 2% and did not exceed admissible/reference values.

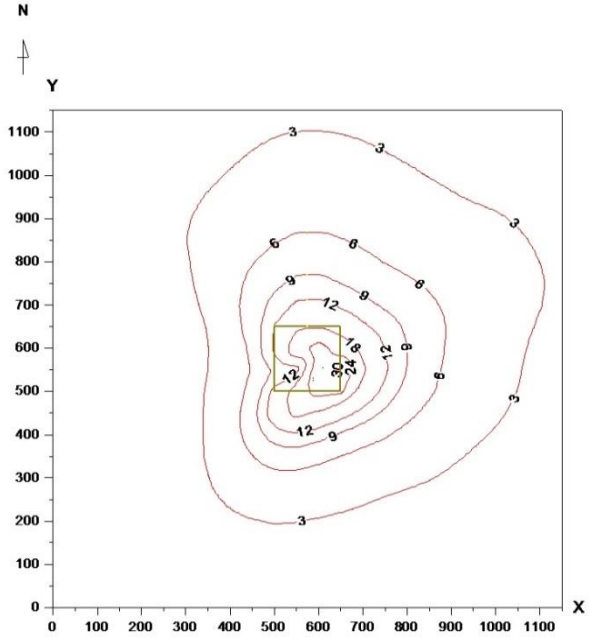


Figure 4. Spatial distribution of isolines of average annual $NO_2$ concentration in air

The maximum calculated value of dust condensation in the analyzed area totaled to 15.82 g/m$^2$/year, i.e. only 7.9% of the reference value (200 g/m$^2$/year).

## 6. Conclusions

Apart from the preparation of the rig and fracturing jobs or hydrodynamic tests, drilling works constitute one of the major stages of shale gas prospecting. Modeling based on real data reveals that they are a significant hazard to the atmosphere because of the nitrogen oxides ($NO_x$) emissions. Such emissions are usually generated by high-power diesel engines powering the rig devices. A mobile boiler room is an additional source of $NO_x$ emissions and also other contaminants. The modeling of dust-gaseous emissions from four diesel engines (1257 kW each) and a mobile boiler room (375 kW) showed that the $NO_2$ concentration in air beyond the rig area can be exceeded, especially in the periods of maximum load of the sources and bad conditions of propagation (state of constant equilibrium in the atmosphere, low speed of the wind). The remaining contaminants generated in the course of diesel and fuel oil in the analyzed sources do not create important hazard for the quality of air beyond the rig area.

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## References

1. BOGACKI M., MACUDA J., 2014, The Influence of Shale Rock Fracturing Equipment Operation on Atmospheric Air Quality, in: *Archives of Mining Sciences*, vol. 59, no 4, p. 897-912.
2. MACUDA J., 2010, Environmental aspects of natural gas production from unconventional deposits, in: *Geological Review*, vol. 58 no 3, p. 266-270 (in Polish).
3. MACUDA J., MARCHEL P., 2011, Environmental impact of drilling works on shale gas prospecting in Poland, in: *Drilling Oil Gas*, vol. 28 no 1-2, p. 263-271 (in Polish).
4. ZAWISZA L. et al., 2007, *Evaluation of natural hazards while prospecting, recognizing and extracting hydrocarbon deposits*. Grant Nr 640/2004/Wn-06/FG-go-tx/D, (in Polish).
5. RAHM B., RIHA S., YOXTHEIMER D., 2011, Environmental water and air quality issues associated with shale gas development in the Northeast. Marcellus Center for Outreach & Research, http://www.marcellus.psu.edu/research/pdf/ChangingEnvironment.pdf (05.06.2016).
6. MACUDA J., KONIECZYŃSKA M., 2015, Environmental Impact of Exploration from Unconventional Gas Deposits in Poland, in: *Ecological Chemistry and Engineering*, vol. 22 no 4, p. 703-717.
7. CATERPILLAR OIL & GAS, 2013, *Power for well servicing*, http://catoilandgas.cat.com/cat-3512-well-servicing (01.06.2016).
8. U.S. ENVIRONMENTAL PROTECTION AGENCY, 2013, *Large Stationary Diesel and All Stationary Dual-fuel Engines, Volume I, Chapter 3: Stationary Internal Combustion Sources*, AP 42, 5th Edition, https://www3.epa.gov/ttnchie1/ap42/ch03/final/c03s04.pdf (01.06.2016).
9. EUROPEAN ENVIRONMENT AGENCY, 2006, *Other mobile sources and machinery. Off road transport. Emission Inventory Guidebook*, http://www.eea.europa.eu/publications/EMEP-CORINAIR/group08.pdf (01.06.2016).
10. POLISH COMMITTEE FOR STANDARDIZATION, 2013, *Fuel for vehicles. Diesel oils. Requirements and research methods*. *PN-EN 590:2013-12* (in Polish).
11. DIESELNET, 2016, Emission standards. Nonroad diesel engines, https://www.dieselnet.com/standards/us/nonroad.php (01.06.2016).
12. MICHAŁOWSKI M., TORA B., ČABLIK V. ČERNOTOVÁ, L., 2012, Wybrane problemy wydobycia gazu łupkowego, in: *Rocznik*

*Ochrona Środowiska/Annual Set Environment Protection*, Tom 14, p. 866-874.
13. MINISTRY OF ENVIRONMENTAL PROTECTION, NATURAL RESOURCES AND FORESTRY, 1996, *Emission indices for contaminants introduced to the atmosphere from the combustion of fuels. Information and guideline materials* (1/96), Warsaw, (in Polish).
14. *Regulation of the ENVIRONMENT MINISTER of 24 August 2012 about the level of some substances in air* (Dz.U. 2012 poz. 1031.), 2012 (in Polish).
15. *Regulation of the ENVIRONMENT MINISTER of 26 January 2010 about reference values for some substances in air* (Dz.U. 2010 nr 16 poz. 87), 2010 (in Polish).

**PROBLEMY EKOROZWOJU – PROBLEMS OF SUSTAINABLE DEVELOPMENT**
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# Model-Driven Engineering and Creative Arts Approach to Designing Climate Change Response System for Rural Africa: A Case Study of Adum-Aiona Community in Nigeria

# Zastosowanie inżynierii sterowania modelami i sztuk pięknych w przygotowywaniu systemu reagowania na zmiany klimatyczne dla obszarów wiejskich w Afryce: przypadek wspólnoty Adum-Aiona w Nigerii

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## Abstract

Experts at the just concluded climate summit in Paris (COP21) are unanimous in opinion that except urgent measures are taken by all humans, average global temperature rise would soon reach the deadly 2$^{o}$C mark. When this happens, socio-economic livelihoods, particularly in developing economies, would be dealt lethal blow in the wake of associated natural causes such as increased disease burden, soil nutrient destruction, desertification, food insecurity, among others. To avert imminent dangers, nations, including those from Africa, signed a legally binding universally accepted climate control protocol to propagate and regulate environmentally-friendly behaviours globally. The climate vulnerability of Africa as established by literature is concerning. Despite contributing relatively less than other continents to aggregate environmental injustice, the continent is projected to bear the most brunt of environmental degradation. This is on account of her inability to put systems and mechanisms in place to stem consequences of climate change. Hence, our resolve to use a combination of scientific and artistic models to design a response system for tackling climate challenges in Africa. Our model formulation encompasses computational model and creative arts model for drawing attention to environmentally friendly behaviours and climate adaptation and mitigation strategies. In this work, we focus on rural Africa to share experience of climate change impact on agriculture – mainstay of rural African economy. We examine the carbon footprints of a rural community in Nigeria – the Adum-Aiona community – as case study and for industrial experience. The authors will provide operational data to substantiate claims of existential threats posed by greenhouse gas (GHG) generation on livelihoods of rural dwellers. The study will also design and test a Climate Change Response System (CCRS) that will enable people to adapt and reduce climate change impact. To achieve the research objective, the researchers will review literature, gather requirements, model the proposed system using Unified Modelling Language (UML), and test CCRS statically. We expect that the implementation of the proposed system will enable people mitigate the effects of, and adapt to, climate change-induced socio-economic realities. This is besides the fact that the empirical data provided by the study will help clear doubts about the real or perceived threats of climate change. Finally, the industrial experience and case study we share from Africa using model-driven engineering approach

will scale up the repository of knowledge of both climate change research and model-driven engineering community.

**Key words:** agriculture, climate change, visual and creative arts model, model-driven engineering, response system

## Streszczenie

Eksperci biorący udział w szczycie klimatycznym w Paryżu (COP21) sugerują, że pomimo mimo podejmowanych działań zaradczych, średnia temperatura na naszej planecie podniesie się wkrótce o $2^0$C. Gdy to nastąpi, społeczno-ekonomiczne podstawy bytu, szczególnie w krajach rozwijających się, zostaną naruszone w wyniku m.in. przewidywanego wzrostu zachorowań, zniszczenia gleby, pustynnienia i braku zabezpieczenia żywności. Aby zapobiec zbliżającemu się niebezpieczeństwu podpisano prawnie wiążący protokół klimatyczny, zaakceptowany także przez kraje afrykańskie. Jego celem jest uregulowanie i wsparcie dla zachowań prośrodowiskowych w skali globalnej. Opisywana w literaturze wrażliwość klimatu w Afryce wydaje się być szczególnie istotna. Chociaż w porównaniu do innych kontynentów jej udział w emisji zanieczyszczeń do atmosfery jest mniejszy, to właśnie ten kontynent ma dotknąć największy poziom degradacji środowiskowej. Wynika to m.in. z braku możliwości wdrażania kluczowych dla klimatu systemów i mechanizmów. Stąd wynika nasza determinacja w opracowaniu kombinacji naukowych i artystycznych modeli, służących jako narzędzia do formułowania systemu odpowiedzi na czekające Afrykę zmiany klimatyczne. Nasze podejście obejmuje modele obliczeniowy i odnoszący się do sztuk pięknych, które mają pomóc w zwróceniu uwagi społeczeństw na niezbędne zachowania prośrodowiskowe. W badaniach koncentrujemy się na obszarach wiejskich w Afryce, aby przedstawić wpływ zmian klimatycznych na rolnictwo, które stanowi podstawę afrykańskiego systemu ekonomicznego. Zbadaliśmy ślad węglowy obszarów wiejskich w Nigerii, we wspólnocie Adum-Aiona. Autorzy przedstawiają dane pokazujące realne zagrożenia dla ludzi, które niesie ze sobą emisja gazów cieplarnianych. Prezentowany jest także test odnoszący się do Systemu Odpowiedzi na Zmiany Klimatu, który pomoże mieszkańcom nie tylko w adaptacji do, ale także w zmniejszeniu konsekwencji zmian klimatycznych. Dyskusja zostanie wsparta przeglądem literaturowym, pomagającym lepiej określić wymagania, które powinien spełniać model, z wykorzystaniem UML. Należy się spodziewać, że wdrożenie proponowanego systemu przyniesie realne korzyści, także te noszące się do uwarunkowań społeczno-ekonomicznych. Rezultaty przeprowadzonych badań empirycznych precyzują zakres zagrożeń związanych ze zmianami klimatycznymi. W końcowej części odniesiemy się do doświadczeń związanych z przemysłem, także w kontekście Afryki. Zastosowanie inżynierii sterowania modelami wzbogaca zakres wiedzy odnoszący się zarówno w kontekście badań nad zmianami klimatycznymi, jak i możliwych zastosowań inżynierii.

**Słowa kluczowe:** rolnictwo, zmiany klimatyczne, wizualny i kreatywny model sztuki, inżynieria modelowa, system odpowiedzi

### 1. Introduction

In this work, we try to measure and simulated a climate-resilient rural Africa using the Adum-Aiona community in Benue State, Nigeria. To achieve this objective, we obtained climate data from the Nigeria Meteorological Agency (NIMET) in the form of its yearly seasonal rainfall predictions spanning 2011-2015. Africa is well known for its reliance on agriculture for socio-economic sustenance (Schroth et al., 2016; Webber et al., 2016). The fact, that this sector is not well developed results in heavy dependence on rain-fed model of agriculture such that weather changes greatly impact of its operations. Though developments in climate change impact other sectors such as transportation, construction, aviation, manufacturing, among others, the agrarian nature of Africa means that particular attention must be given to the agriculture sector (Perez et a., 2015; Li et al., 2015). Hence, the seasonal rainfall predictions of many national meteorological agencies across Africa are predominantly utilized in the agricultural industry (Seo, 2015).

Overtime, the failure of African governments to develop alternative to rain-fed agriculture such as irrigation farming means that the socio-economic lives of the people are impeded when factors such as weather change is not favourable to rain-fed agriculture (Jones et al. 2015). Incidences of drought, delayed rainfall, early cessation and dry spells take heavy toll on the sustenance of lives. The immediate consequences are food insufficiency and insecurity, hunger, poverty, unemployment and attendant social vices such as kidnapping, prostitution, and terrorism. Though there has been deliberate policies in the direction of encouraging irrigation farming, policy inconsistency and somersault over the years in various African countries has been the bane of the project (Kusangaya et al., 2014). As a result, frameworks like dams and river basins that known for potentials to channel surface water for irrigation farming are abandoned or left uncompleted.

On the other hand, activities of urban and rural dwellers continue to heighten greenhouse gasses (GHGs) emission. While in the urban African settlements, carbons emissions are pronounced through the burning of hydrocarbons (Steynor et al., 2016) in

petroleum products such as kerosene, petrol and diesel for transportation, construction and manufacturing, rural communities engage in environmental injustice by felling trees during land preparation for farming, burning of firewood as source of cooking energy, and deliberate deforestation for purposes of transacting log business (Chidiebere et al., 2016). The aggregate effect is that the dearth of clean energy in Africa has increased the contribution of Africa to the rise in global temperature that is feared to be approaching the dangerous 2$^{o}$C threshold, except concrete steps are taken. Even more concerning is that though Africa contributes least to GHGs emission, ozone layer depletion and aggregate rise in global temperature among all the continents, studies have shown that it suffers most in terms of bearing climate change burden. This is because it has weak climate change response mechanism (Clarke et al., 2016).

In this study, we focus on filling this gap by designing a Climate Change Response System (CCRS). The policy thrust of CCRS is to sensitize people on ecologically friendly behaviours and climate adaptation and mitigation techniques leveraging creative art models such as dance, drama, and visual aid (graphics), communication. Though we take a general look at climate change impacts on both urban and rural Africa, our particular interest is on rural Africa as vast majority of agricultural activities take place there and majority of Africans dwell there. For case study and industrial experience, we use the Adum-Aiona community in Nigeria, precisely in Benue State. The community is an agricultural hub and its host state, Benue, is known as the food basket of the nation. CCRS captures initiatives that promote environmentally friendly behaviours as well as spell out adaptation and mitigation techniques for surviving climate-challenged environment. Using model-driven engineering approach, we design CCRS using unified modelling language (UML) and test the proposed system statically (Sirohi, Parashar, 2013; Gorton, 2011). Besides closing a contextual gap, the case study and industrial experience shared add to bodies of knowledge of both the model-driven research community and climate change research community. The evidence provided by way of literature review of various case studies, and operational data from the Nigerian Meteorological Agency on Seasonal Rainfall Predictions also help in substantiating the existential threats posed by climate change to the human race.

The remaining segments of the article is partitioned thus: In Section 2, there is review of literature; adopted methodology for the research is outlined in Section 3; Section 4 discusses results; and in Section 5, the work is concluded.

## 2. Review of Literature

### *2.1. Climate Change and El Niño in Africa*

A change in weather patterns measured in statistical distribution, which lasts for a length of time, say decades to millions of years, is termed climate change. Put in another fashion, it refers to average weather conditions alteration. Climate change can also be seen as more or fewer extreme weather events which implies time change in weather around longer-term average conditions. Factors such as changes in solar radiation received by Earth, biotic processes, volcanic eruptions and plate tectonics are responsible for climate change. Also, some human activities are direct or indirect causes of contemporary climate change, called global warming (Kahsay, Hansen, 2016).

Organizations, like Climate Action Network Europe and Germanwatch, are known to be the publishers of the annual publication called *The Climate Change Performance Index* (CCPI). It is a barometer for evaluating 58 countries with regards to climate protection performance and these countries are responsible for more than 90% of world energy-associated $CO_2$ emissions. In 2013, CCPI publication covered $CO_2$ generated from sources such as fossil fuels, with the exception of emissions from the shipping sector. Subsequent CCPI publications took into cognisance emissions from waste, deforestation and agriculture. The evaluation is made up of the following compositions: emission trend is 50 %, emission level constitutes 30% while the remainder of 20% comes from assessment of over 200 experts on national and international climate policy. Recent results (as published in December 2014) indicate that more efforts are required to avert dangerous climate change. Hence, no country was ranked one to three in the 2015 results. However, Denmark was acknowledged for her efforts even as she topped the list (Calzadilla et al., 2014).

El Niño Southern Oscillation (ENSO) has a warm phase known as El Niño. In the region of the International Date Line and 120°W (off the Pacific coast of South America inclusive), there is a band of warm ocean water that develops in the central and east-central equatorial Pacific which is associated with El Niño. ENSO can also be seen as the cycle of warm and cold temperatures which is measured by sea surface temperature (SST) of the tropical central and eastern Pacific Ocean. Typically accompanying El Niño is low air pressure in the eastern Pacific and high air pressure in the western Pacific. However, the cool phase of ENSO is known as La Niñais and normally characterised by SST. In the eastern Pacific, it is below average but the air pressures are high in the eastern Pacific and recording low in the western Pacific. Outcomes of the ENSO cycle – both El Niño and La Niña are directed by global changes in temperatures and rainfall (Young et al., 2016).

Study is ongoing on mechanisms that cause the oscillation.

Developing countries such as African countries depend largely on agriculture and fishing for survival. The most affected countries are those bordering the Pacific Ocean (Wündsch et al., 2016). In recent times, climate change tends towards more extreme El Niños, as shown by measurements and simulations. In Africa, the impact of the phenomenon differ from one region to another – in some parts such as Kenya, Tanzania, and South Africa, long rains and wetter-than-normal conditions are experienced between March and May. In others, drier conditions than normal exist such as in Zambia, Zimbabwe, Mozambique, and Botswana from December to February. Direct impacts of El Niño responsible for drier conditions are experienced in some parts of Northern Australia and Southeast Asia resulting in worsening haze, intense bush fires, and significant reduction in quality of air. Conditions that are drier than normal characterise certain parts of the globe at some time of the year (Calatayud et al., 2016).

*2.2. Sustainability and Social Consequences of Climate Change in Africa*

Human survival is a function of the environment. All aspects of human survival need structures that operate in a given environment, social services (health, education and agriculture) inclusive. The decimation of the environment means livelihoods are directly or indirectly impacted upon negatively. In the Horn of Africa (Ethiopia, Eritrea and Somalia) for example, there is presently humanitarian crisis partly due to drought and food shortage as a result of unfavourable and unpredictable climatic conditions (Clarke et al. 2016). The consequent desert encroachment has not only left in its trail hunger but also diseases (Grace et al., (2015).

The impact of desert encroachment is also taking its toll on Northern Nigeria, where herdsmen are known to be leaving the area massively for Southern Nigeria in a bid to sustain their animals as a critical component of their pastoral (nomadic) life. The adverse effect of climate change has not only shrunk water sources for human and animal consumption (Kusangaya et al., 2014) but equally impacted on irrigation farming (Kahsay, Hansen, 2016; Calzadilla, 2014). On the other hand, the massive migration has resulted in ethno-religious crisis and even ethnic cleansing (Clionadh et al., 2015) in some extreme cases due to frequent clashes between farmers and herdsmen over grazing lands. Consequently, the Nigerian government is currently putting agricultural policies in place in the direction of creating grazing reserves to check the incessant loss of human lives and cater for the animals in the most efficient and effective manner for optimal productivity.

In the coastal cities of Africa, ocean surge has been known to destroy corporate buildings hosting multinational companies and destroying road infrastructure thereby hindering coastal economies (Wündsch et al., 2016). Also, buildings whose initial plans did not envisage or factor in harsh elements of the unfolding climatic conditions, are suffering structural defects (Chinowsky et al., 2014). This has serious implications for commerce and socio-economic development. In Eastern Nigeria, gully erosion has decapitated valuable lands that should have been used for commerce, industries and agriculture. Huge budgetary allocations that otherwise should have been used for enhancing the wellbeing of the citizenry through the provision of social services are being channelled to ecological management (Klausbruckner et al., 2016).

As a mitigation measure, there has been increased emphasis on the use of renewable energy in Africa (Fant et al., 2016) but lack of infrastructure has been the bane of such sustainable development initiative.

*2.3. The Nigerian Metrological Agency (NIMET)*

The Nigerian Meteorological Agency (NIMET) is a government parastatal that undertakes the production and issuance of seasonal rainfall prediction (SRP) for Nigeria in line with the agency's responsibility of advising government on all matters bothering on weather and climate. The SRP has gained popularity over the years and it is now largely patronized by stakeholders in climate-sensitive sectors of the economy (Bellprat et al., 2015). The scientific information it garners serves as input in planning and decision making.

The predictions are hinged on the intense tele-link between Sea Surface Temperature anomalies, El-Nino/Southern Oscillations (ENSO), and rain-bearing systems in Nigeria. In some years, SRP is predicted under the La-Nina phase and later revised to the neutral phase of the ENSO phenomenon. Despite the alternating affairs between La-Nina and El-Nino, Nigeria is characterised by ENSO-neutral conditions as the most dominating climate scenario. In most parts of the country, the ENSO-neutral phase is responsible for normal weather and climate conditions. In fulfilment of its statutory function of providing credible meteorological information, early warnings, forecasts, and advisory to guarantee informed decisions in all weather-sensitive and climate-conscious sectors of the economy, NIMET predicts annually and presents same to stakeholders for contributions on the socio-economic impacts prior to making predictions public. The release of the SRP is done early in the year so that policy makers will have sufficient time to factor in the critical information and advisories contained in it into the process of decision-making. This way, risks associated with harsh weather and climate are mitigated by the agency, and safety of lives and property guaranteed (Zinyengere et al., 2013). This initiative contributes significantly to Nigeria's sustainable socio-economic development.

NIMET relies on the following input data for the production of the annual SRP:

- Historical daily rainfall, maximum and minimum temperatures.
- Daily solar radiation data.
- Phenological and soil information data.
- El Nino/Southern Oscillation (ENSO) phase as defined by the Sea Surface Temperature irregularities.
- Rain-related synoptic systems for Nigeria.

*2.4. A Model-driven Engineering Approach*

The term Model-driven Engineering (MDE) is a methodology for software development with focus on exploiting and creating models of domain (Martínez-García et al., 2015; Wautelet, Kolp, 2016). The domain models (task model, quality model, data model, among others) are conceptual models of all aspects of a problem. For example, a climate change response application domain would emphasize representations of environmentally friendly behaviours, climate data local to a region, adaptation and mitigation techniques using standard modelling tools. Thus, MDE concentrates on representing knowledge and tasks in abstract format for guiding a domain application. Computing or algorithmic concepts are not its focus (Riesenfeld et al., 2015; Calegari et al., 2016).

MDE has potential for increasing productivity in that it maximizes systems compatibility by reusing models that are standardized (Davies et al., 2014). Also, by relying on models of the application domain with recurring design patterns, it simplifies the process of design (Gurunule, Nashipudimath 2015). Finally, individuals and teams jointly working on systems can have better communication owing to the use in the application domain of standardized practices and terminology (Barbier et al., 2015).

An MDE modelling paradigm is effective if two conditions are fulfilled – the models make sense to a user that is conversant with the domain, and secondly, they are capable of serving as the basis for implementing systems (da Silva, 2015). Collaborative efforts are involved in models development via intense communication between designers, product managers, users, and developers of the domain application. The completion of the models enhances the development of software and systems (Davies et al., 2015).

Some popular MDE projects includes (Ciccozzi et al., 2013; Rutle et al., 2015): Computer-Aided Software Engineering (CASE), Unified Modelling Language (UML), Object Management Group (OMG), Eclipse ecosystem of programming and modelling tools (Eclipse Modelling Framework), model-driven architecture (MDA), among others. Studies have shown that MDE technologies are promising in addressing the inefficiency of third-generation languages with respect to alleviating platform complexity and expressing domain concepts maximally (Hutchinson et al., 2014; Lütjen et al., 2014).

It is worth reiterating that modern systems design demands efficiency in handling their dynamic complexity (Cervera et al., 2015). In order to reduce the complexity, there is need for overhauling the entire system development process and take a second look at the age-long division among development phases. Since MDE shifts the focus from code to models, it is a veritable way of mitigating development complexity (Wehrmeister et al., 2014). The effective utilization of MDE reduces costs and risks in a number of ways: facilitating efficient modelling and analysis of functional and non-functional requirements; defining and implementing loosely coupled components into assemblies as a way of improving reusability; and in the course of development, making provision for automation where necessary (García-Magariño, 2016).

*2.5. Creative Arts Model for Climate Change Sensitization and Mobilization*

Creative Arts is the study of the power to form or to build out of nothing or something by force of imagination and talents. It is sub divided into two, namely Visual and Non-visual art (Babatunde, 2007). Visual arts are those aspect of art whose products are visible while Non-visual arts are those whose product cannot be seen with the naked eyes. Non-visual art are mainly for entertainment and recreation. While visual arts are for either beautification or applied.

For the sake of this study, the creative art model for climate sensitization and mobilisation includes one aspect of Non-visual arts and one aspect of Visual arts that has been employed for their effectiveness on how they have been used in different scenarios to effectively tackle societal issues. The two aspects are performing art (Non-visual) and Graphic art (Visual).

Performing (Non-visual) Art includes dance and drama which is performed to inform, sensitise or entertain an audience. Carnival performance is also an aspect of performing art that has been used to sensitise the society in divers ways. According to Akande (Akande, 2016), top government officials unveiled the theme of the 12th edition of the carnival which took place in 2015 as *Climate Change*. They remarked that it was necessary to explore the subject further, as more and more countries in the world continue to show concern for the environment. Thereafter, they led other government officials, the locals and revellers in a five million tree-planting campaign which was also in tune with the theme of the 2015 event (Fig. 1). According to Akande, the governor maintained that his administration will plant five million trees to support afforestation and climate change. In company of acrobatic dancers and music blasting trucks, richly costumed girls in green led each group as revellers took over the carnival routes cheering participants. Other side attractions included celebrities, masquerades, exquisite floats, and notable disc jockeys. Notably, the designs of the floats

Figure 1. Richly costumed girls in green dancing and leading the group at 2015 Calabar carnival in Nigeria tagged *Climate Change*, source: *The News Mongers*


Figure 2. Dignitaries dressed in foliages at 2015 Calabar carnival in Nigeria tagged *Climate Change*, source: *Gist Nigeria Blog*


Figure 3. Graphic art *Do Not Cut Trees Sign*, source: *Free digital photos*

Figure 4. Graphic art *No tree felling, no fires*, source: *Dreams time*

were carefully crafted to depict *Climate Change* (Fig. 2).

True to its name, Graphic (Visual) Art has to do with vision or sight i.e. art works that can be seen. Visual art is also sub divided into the fine and applied arts. Graphics falls under applied art because it aids understanding in reading through visual images and text. Graphic design is a commercial art which service our visual communication system in producing designs like posters, signage, Book covers, labels, packages and so on. Maa Illustrations (2015) opine that to capture public attention, visual images play a significant role. The essence of illustrations in advertising is to pass a strong message to the audience. It presents a strong appeal to the target audience to focus on the advertisement.

Overtime, graphics design as part of the creative art model for climate sensitization and mobilisation has yielded effective way of communicating to members of a society through visual presentations combined with text, it simplifies ideas and makes it understandable to an averagely educated community. Graphics has been used to pass on simple but clear messages of prohibitions such as *Do not cut trees* (Fig. 3) and *No felling and burning trees* (Fig. 4).

Creative arts model for Climate Change Sensitization and Mobilization is a model that is an effective way of disseminating, sensitizing and informing the society of the need to be cautious. It catches the people's attention in terms of performing arts. The society is very much in tune with dance, drama and songs and would quickly align with whatever information that is coming out of these and that is why performing art is strategic to information broadcast to the people. Graphics art as a second tool under this model presents dual advantage for this course. It simplifies information for both learned and an average learned society with the utilisation of images and text.

The creative art model as presented in this study will be appropriate to disseminating information to the populace of Adum-Aiona Community regarding climate change, especially if this model is presented in the indigenous language of the people.

### *2.6. Related Work*

In the literature, previous works that have bearing with model-driven engineering and climate change are as follows: (Lukman et al., 2013; Brunelière et al., 2014; Bubeck et al., 2014; Panesar-Walawege et al. , 2013; Cuadrado et al., 2014; Chabridon et al., 2013; Brambilla, Fraternali, 2014), discussions centred on MDE. The application of model-driven engineering in various fields of endeavours such as software development, industrial robotics, safety stand-

ards, software enterprises, web user interactions, among others were discussed. The authors were unanimous in their submissions that MDE not only enhances stakeholders' understanding of proposed system, it elicits support from stakeholders and engineers their commitment to the implementation of the system. This way, MDE contributes immensely to problem solving. As exhaustive as the discussions were, the authors did not mention the application of MDE for developing climate change response system. This is our key motivation in this work.

Ofoegbu et al. (2016) carried out an assessment of the adaptive capacity of forest-based rural communities and their coping strategies against climate variability using a South African Vhembe district as case study. The study has striking resemblance with ours in that it highlights the many coping initiatives used by forest-based rural settlers in Vhembe District of South Africa in order to acclimatize with climate variability so as to cushion attendant difficulties. The study observed that the nature of climate variability and extreme weather were chief determinants of survival strategies adopted such as rainwater harvesting, for coping with erratic rainfall, tree planting around houses and on farm land to counter the effects of extreme temperature. In addition, household and community demographic characteristics such as education and skills levels impacted on their response capabilities. Other critical factors for adapting and mitigating climate challenges include availability of forest products, institutional services and social infrastructure such as markets and water. The authors concluded that rural communities' resilience to climate change and variability challenges could be enhanced strengthening household's capacity and community infrastructural development. As closely related as the study is, it focused on the local exigencies of a South African communities whereas our study focus on Nigerian communities, using one as case study.

Steynor et al. (2016) shared experiences from urban Africa on co-exploratory climate risk workshops. The treatment opined that co-production has been acknowledged as cardinal to proper use and uptake of climate information into decision-making. Nonetheless, the authors observed, the success of co-production is a function of the natural understanding of the domain in which it is implemented. The article x-rayed the context for a place-based co-exploratory analysis of parameters such as climate risks, the elements and steps incorporated in the approach, among others. The co-exploration approach complements the objectives of the Global Framework for Climate Services just as it underscores heightened integration of climate information into urban adaptation planning in Africa. Despite stressing the benefit of climate time and sufficient information in planning, decision making and project execution in urban Africa, less attention was given to the climate change challenges of rural Africa which forms about 70% of the continent.

On his part, Seo (2014) relied on Agro-Ecological Zone (AEZ) techniques to examine how climate change impacts on decisions bothering on micro farming in sub-Saharan Africa (SSA). Relying on observed farming decisions in SSA, the work focused on understanding agriculture and assessing climate change impact on it with the aid of AEZ methods. Using the AEZ categorization of African continent and the idea of the Length of Growing Period (LGP), the author explained AEZ method. The World Bank household surveys which covered about 8000 farms spread across 9 sub-Saharan countries provided statistics on Farmers' decisions. Despite providing informed direction on effect of climate change on agriculture, the article did not suggest a climate change response system, the main motivation of our study.

In summary, none of the studies reviewed dwelt on closing the gap of designing a climate change response system (CCRS) using model-driven engineering for rural Africa. This is the gap we address in the following sections of the article.

## 3. Methodology

Our study focused on the carbon and ecological footprints of the Adum-Aiona community, estimating the impact of human activities on greenhouse gases (GHGs) emission into the atmosphere and destruction of soil texture that paves way for soil erosion and allied ecological problems. Our study revealed that both carbon and ecological footprints impact adversely on the livelihoods of the community whose mainstay is agriculture. We tabulate our findings as shown in Table 1.

Against the backdrop of established negative impacts of climate change on socio-cultural and socio-economic lives of Africans in general and rural Africans in particular (Raleigh et al., 2015), a response system that outlines measures for adapting to the new climate-engineering environment and that will also mitigate the adverse resultant effects will be handy in alleviating the sufferings of the people. The response system should also be proactive by adopting measures that promote ecologically-friendly disposition so that people are conscious that their environment-related behaviours have consequence for their continues survival (Grace et al., 2015).

There is no gainsaying the fact that vast majority of Africans rely on agriculture for survival. Hence, weather uncertainties as dictated by climate change has direct implications for livelihoods as Africa relies largely on rain-fed agriculture (Lim et al., 2016). The case study used is the Adum-Aiona community in Benue State of Nigeria. Like many rural African communities, it is an agrarian settlement in the Middle Belt (North Central) region in Nigeria. The so-

Table 1. Carbon and ecological footprints of Adum-Aiona Community

| SN | Activity | Impact on Global Warming (El Nino) and Ecology | Effects |
|---|---|---|---|
| 1. | Cooking using firewood | Emission of greenhouse gases (GHGs) | Excessive heat waves that cause human discomfort and encourage spread of diseases such as meningitis. |
| 2. | Pressing iron (charcoal iron) | Emission of $CO_2$ into atmosphere | Heated atmosphere resulting in depletion of ozone layer and attendant consequences. |
| 3. | Tree felling | Destruction of trees that utilizes $CO_2$ for photosynthesis, in the process reducing $CO_2$ in the atmosphere. Also, tree roots hold soil tight for water absorption, preventing flooding. Trees absolve GHGs that contribute to GW and CC. | Erosion and degradation of soil nutrients that reduce agricultural productivity leading to food insufficiency and insecurity, unemployment and social tensions. |
| 4. | Bush burning | Release of GHGs into atmosphere | Destruction of soil texture, flora and fauna, impacting on agricultural productivity, hunger and poverty. |
| 5. | Body warming using firewood | Emission of $CO_2$ into atmosphere | Heated atmosphere resulting in ozone layer depletion and related consequences |
| 6. | Food preservation through smoking | Release of $CO_2$ into atmosphere | Heated atmosphere resulting in ozone layer depletion and related consequences. |
| 7. | Harmful farming practices | Destroyed soil texture, hence decreased capacity to absolve water leading to flooding | Flooding destroys means of livelihoods and further impoverish the people. |
| 8. | Indiscriminate burning and dumping of waste products | Heated and polluted atmosphere as well as destruction of soil texture | Excessive heat waves and depletion of soil structure. These encourage heat-borne diseases, soil erosion and soil nutrients depletion. |

cio-economic lives of the people revolve around rain-fed agriculture with crop planting done during raining season while the dry season is used for harvesting and processing. The raining season typically spans the months of March to October while the dry season covers November to February. Typical crops planted include food crops such as yam, cassava, maize, sorghum, millet, and beniseed. Tree crops found in the community include palm trees and cashew trees while fruits include mango and orange. The seasonal rainfall predictions for year 2016 by NIMET suggests the country will experience late onset of rains and early cessation with dry spells in-between. As indicated in the use case diagram showing the CCRS above, for purposes of acclimatization and mitigation of the consequences of this climate change fall-out, farmers in Adum-Aiona have to be sensitized and educated on climate resilient agriculture via the instrumentality of both formal and informal institutions. Formally, extension services will be used to disseminate information on climate-compliant agricultural practices and inputs as well as rainfall prediction information by NIMET. Informal institutions like worship places (particularly churches since the people are predominantly Christians), town hall meetings, family meetings, and age-grade meetings are further avenues that could be explored for the same purpose which are quiet potent for the domestication and ownership of the climate change response system. The use of drama, dance drama, dance and songs performed in the local Idoma language during informal gatherings will go a long way in driving home the message of potential challenges posed by climate change and the need to take proactive measures. In addition, visual aid such as posters and hand bills illustrated and written in the local language and posted at strategic positions will also lend a voice to the campaign.

In the meantime, our study has revealed that farming practices of the Adum-Aiona farmers could exacerbate climate change impacts. Some of the environmentally unfriendly behaviours include indiscriminate tree felling during land preparation, burning of fossil fuel through the use of firewood for cooking, and indiscriminate cutting of trees for logs (Klausbruckner et al., 2016). While the community justifies deforestation by citing agricultural and commercial expediencies, the use of firewood for cooking has been substantiated by the lack of alternative source of clean energy. Though the community is located in Nigeria, an oil producing country, the inability of the country to curtail gas flaring and use same for supplying clean gas energy means the people continue to burn hydrocarbon fossil fuels – firewood, kerosene, petrol and diesel for survival. Even though the Adum-Aiona community's vegetation is relatively green and dense, these human activities certainly escalate emission of greenhouse gases

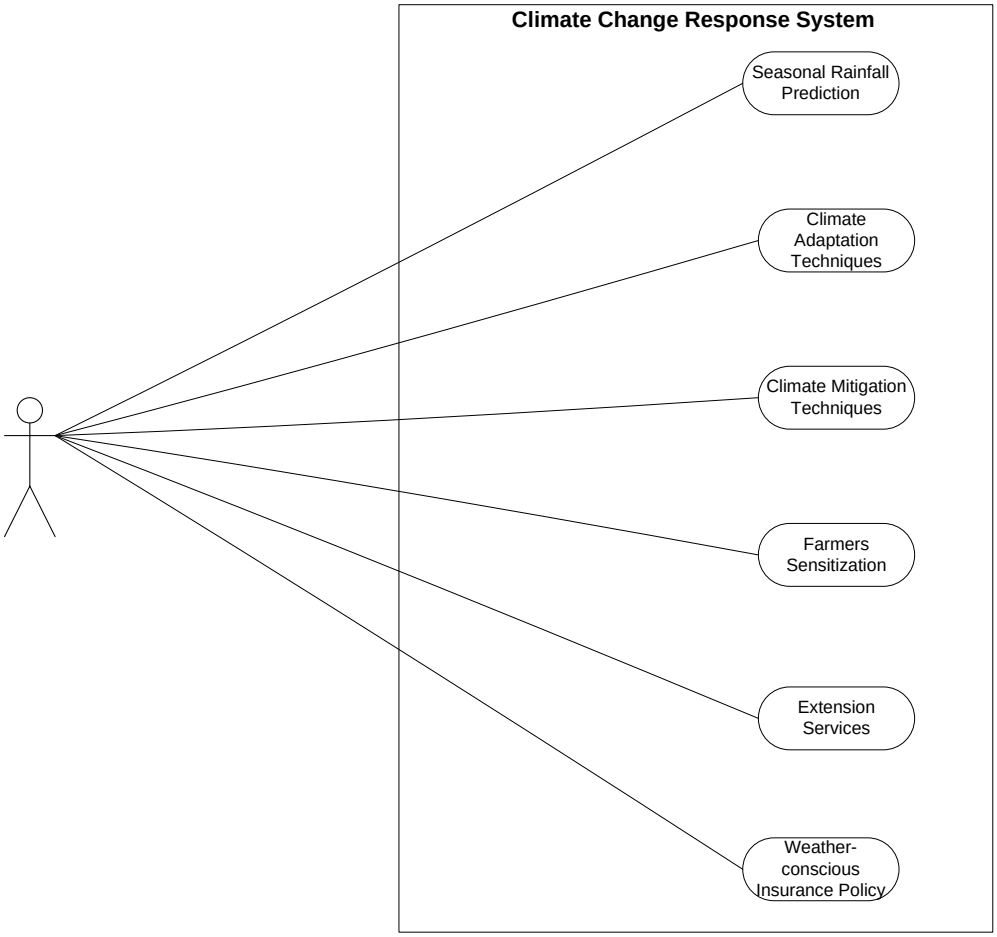


Figure 1. Use Case Diagram for the Climate Change Response System (CCRS)

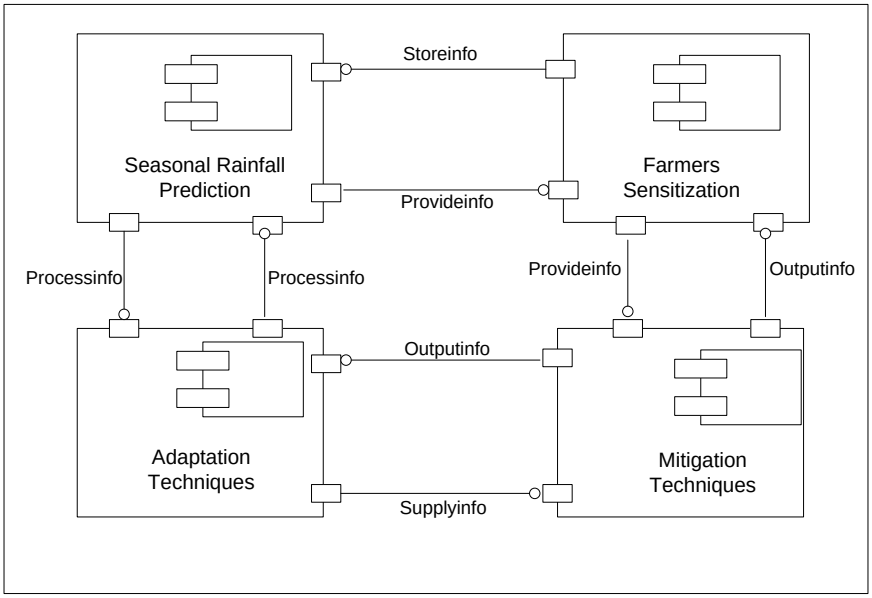


Figure 2. CCRS component diagram

(GHGs), contribute to rise in global temperature tending towards the 2ºC mark, and deplete the ozone layer (Chinowsky et al., 2014). Hence, CCRS contains a component that not only sensitizes and educates the rural dwellers on climate adaptation techniques but also enlightens them on ways of mitigating carbon emissions (van Wesenbeeck et al., 2016).

*3.1. Requirements Analysis and Modelling*

Our proposed Climate Change Response System (CCRS) contains mechanisms (actions) that promote environmentally friendly disposition and climate-resilient agriculture as depicted in Fig. 1 using Unified Modelling Language (UML). The requirements as captured in the diagram include uses cases (actions) such as *Seasonal Rainfall Prediction, Climate Adaptation Techniques*, *Climate Mitigation Techniques*, *Farmers Sensitization*, *Extension Services* and *Weather-conscious Insurance Policy.*

The *Seasonal Rainfall Prediction* will empower farmers and other climate change stakeholders with information on rainfall patterns as provided by the national meteorological agencies such as the Nigerian Meteorological Agency (NIMET). This will enhance planning, decision making and execution of socio-economic projects in agriculture, construction, transportation, water resource management, telecommunication, among others (Moyo, Nangombe 2015).

The *Climate Adaptation Techniques* component will highlight to farmers and other stakeholders updated techniques for adapting to the climate-induced environment. They include, but not limited to, construction of dams and river basins for harnessing surface and underground waters for irrigation, domestic and industrial purposes. Others are digging of wells, planting crops with short life span, sowing disease resistant crops, growing climate-resistant crops, and provision of social infrastructure and amenities (Fant et al., 2016).

The *Climate Mitigation Techniques* sub-system will provide information on measures to reduce emission of greenhouse gases (GHGs). This includes afforestation, discouraging bush burning, recycling of waste products, and use of clean energy instead of hydrocarbon energy, among others.

The *Farmers Sensitization* use case outlines the use of Creative Art models such as dance, drama, posters and hand bills, dance drama, among others through informal institutions such as worship places, family meetings, festivities, age group meetings, etc. for sensitizing and educating farmers on climate change challenges and ways to adapt and mitigate them. This advocacy initiatives are aimed at helping rural dwellers internalise and institutionalize ecologically friendly behaviours, adapt to climate-induced environments and atmosphere, and mitigate the challenges posed by weather and climate vagaries.

The *Extension Services* is a system component that highlights the various services that government Extension Services render to farmers viz-a-viz ecologically friendly behaviours, climate resilient agriculture and climate change mitigation initiatives. Besides traditional extension services such as information on new farming techniques, new agricultural inputs, irrigation, disease resistant crops, drought-resistant crops, there is increased advocacy by climate experts that seasonal rainfall predictions should be an integral part of the extension service package on account of the overbearing impact of climate on agriculture (Kahsay, Hansen, 2016; Calzadilla et al., 2014).

The *Weather-conscious Insurance Policy* is a safety net measure for losses that may be incurred by farmers as a result of carbon and ecological footprints (climate change-induced challenges) such as drought, flood, late onset and early cessation of rains, dry spells, among others (Perez et al., 2015; Kahsay, Hansen, 2016; Bellprat et al., 2015; Zinyengere et al., 2013).

*3.2. System Design*

Though there are many functionalities offered by CCRS, they can be broadly categorised into four cardinal components, namely *Seasonal Rainfall Prediction*, *Farmers Sensitization*, *Adaptation Techniques* and *Mitigation Techniques* as shown in the Component Diagram in Fig. 2.

The class diagram in Fig.3 captures interactions among these sub-systems. Both component and class diagrams graphically indicate interactions among the four core components of CCRS – *Seasonal Rainfall Prediction*, *Farmers Sensitization*, *Adaptation Techniques* and *Mitigation Techniques* with varying details. While the component diagram depicts these sub-systems as loosely coupled components capable of independence to some extent, the class diagram gives details of attributes, methods and cardinality. In summary, CCRS relies on *Seasonal Rainfall Prediction (SRP)* for climate data that are disseminated to stakeholders including the rural farmers for purposes of planning, decision making, and execution of socio-economic projects that enhance livelihoods. The *SRP* data serve as input into Farmers *Sensitization* that encompasses the use of advocacy and climate change education through formal and informal institutions using creative arts models (dancing, graphics, posters, handbills, etc.) to drive climate change messages. The interaction with *Adaptation Techniques* sub-system ensures that farmers are abreast of measures such as climate-resistant crops, use of dams and river basins for irrigation farming as alternative to rain-fed agriculture, among other adaptation measures. Finally, the system interaction places the onus on the *Mitigation Techniques* component to avail farmers information on measures to reduce impact of climate change such as afforestation, proper waste disposal initiatives, use of clean energy as alternative to firewood and other sources of fossil fuels, among others.

The database platform of the CCRS is hinged on Seasonal Rainfall Prediction (SRP) data whose entities and relationships are shown in the entity relationship diagram (ERD).

The narrative of the ERD is to the effect that every state in Nigeria has an SRP made available by NIMET. The attributes of a state include cities, *longitude* and *latitude* while the seasonal rainfall predi-

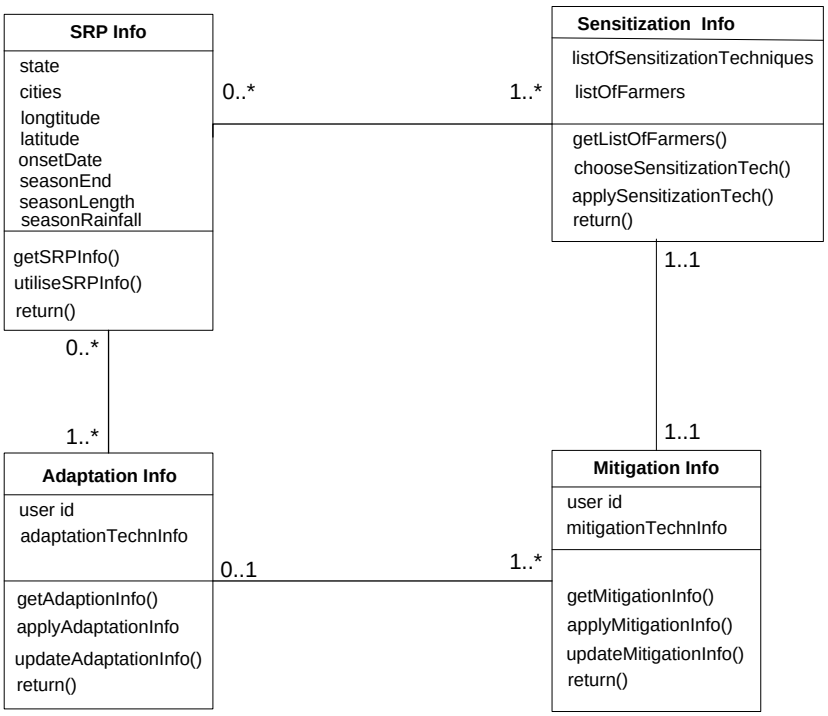


Figure 3. Class Diagram for the Climate Change Response System (CCRS)

ction is characterised by attributes such as *onset date*, *season end*, *season length* and *season rainfall*. The ERD further specifies that every state must belong to one of the agro-ecological zones in Nigeria (*Sahel Savannah, Swamp Forest, Guinea Savannah, Tropical Rain Forest, Sudan Savannah*).

*3.3. System Verification and Validation*

The climate change response system was validated and verified for requirements-compliance and process-correctness of the climate change adaptation and mitigation architecture by checking the different model representations – design documents, requirements documents, and pseudocode. The focus was to ensure that user requirements were well catered for in each model representation. Also, to be sure that the climate change adaptation and mitigation techniques meet ecologically-friendly and climate-resiliency needs rural dwellers in Adum-Aiona community and other similar rural communities in Africa.

The essence of the validation phase is to scale up confidence that the climate change response architecture is fit for purpose (Gorton, 2011). Our technique for validating this architecture is purely static verification and validation (Sirohi, Parashar, 2013) which uses test scenarios for manual testing of the architecture. The essence is to ascertain if flaws exist in the CCRS design so as to correct them prior to implementation.

We verified and validated the CCRS architecture by checking the various model abstractions – design documents, requirements documents, and pseudocode to ascertain that sufficient mechanisms that drive environmentally friendly behaviours and promote climate-resiliency have been built into the proposed CCRS. The requirements traceability matrix is shown in Table 2.

## 4. Results and Discussion

*4.1. Discussion of Outcomes*

NIMET has provided the 2015 SRP (prediction) in fulfilment of its statutory obligation to make available credible meteorological information, advisory, forecasts, and early warnings to guide informed decisions in sectors that are climate and weather-sensitive such as agriculture, construction, etc. Prior to public presentation, the prediction is scrutinized by major stakeholders with a view to making inputs.

Our study focused on Adum-Aiona Community in Orokam, Benue State. Hence, we extracted data from NIMET on the 2015 seasonal rainfall predictions for Benue State located in the middle-belt region of Nigeria. After a careful study of the data, we observed that the database needed to be cleaned up (as there were clear instances of duplicated data) for expected research outcome to be achieve. Hence, we normalize the data by eliminating duplicates, with a new database as shown in Table 3.

The statistics above show the impact of El Nino and climate change on seasonal rainfall pattern in Benue State, North-Central (Middle-Belt) Nigeria. However, for comparative analysis, we further provide seasonal rainfall patterns of the Adum-Aiona community and its surrounding environments in Benue State using SRPs for 2011-2014 as shown in Table 4.

Table 2. Requirements traceability matrix

| Requirement ID | Climate Requirements | CCRS Mechanism | Verification and Validation |
|---|---|---|---|
| CCRS01 | Stakeholders to adequately be informed about weather and climate vagaries for planning, decision making and execution of socio-economic initiatives | The Seasonal Rainfall Prediction sub-system | Catered for |
| CCRS02 | Advocacy campaign and education of farmers for ecologically-friendly behaviour | The Sensitization Information sub-system | Catered for |
| CCRS03 | Adaptation for climate-induced environment for survival | The Adaptation Techniques sub-system | Catered for |
| CCRS04 | Minimizing the impact of global warming and El Nino on means of human livelihoods | The Mitigation Techniques sub-system | Catered for |

Table 3. Normalized 2015 Seasonal Rainfall Predictions for Benue State, Nigeria (Source: NIMET)

| State | City | Longitude | Latitude | Onset date | Season end | Season length days | Annual Rainfall (mm) |
|---|---|---|---|---|---|---|---|
| Benue | Gboko | 09.00 | 07.32 | 11/4/2015 | 26/11/2015 | 231 | 1484 |
| | Markurdi | 08.54 | 07.73 | 1/5/2015 | 17/11/2015 | 200 | 1068 |
| | Otukpo | 08.14 | 07.20 | 9/4/2015 | 27/11/2015 | 233 | 1519 |
| | Aliade | 08.48 | 07.30 | 10/4/2015 | 26/11/2015 | 231 | 1490 |
| | Oju | 07.91 | 07.38 | 11/4/2015 | 26/11/2015 | 229 | 1466 |
| | Ugbokpo | 07.88 | 07.66 | 15/4/2015 | 23/11/2015 | 223 | 1388 |
| | Wanunne | 08.89 | 07.57 | 13/4/2015 | 24/11/2015 | 225 | 1413 |
| | Anyiin | 08.58 | 07.71 | 15/4/2015 | 23/11/2015 | 222 | 1375 |
| | Okpoga | 07.80 | 07.04 | 7/4/2015 | 29/11/2015 | 236 | 1567 |
| | Orokam | 07.55 | 06.97 | 7/4/2015 | 30/11/2015 | 238 | 1589 |
| | Egumale | 07.96 | 08.80 | 5/4/2015 | 1/12/2015 | 242 | 1643 |
| | Idekpa | 07.93 | 07.23 | 10/4/2015 | 27/11/2015 | 233 | 1510 |
| | Obagaji | 07.91 | 07.88 | 17/4/2015 | 21/11/2015 | 219 | 1330 |
| | Kyado | 09.72 | 07.65 | 14/4/2015 | 23/11/2015 | 224 | 1391 |
| | Zaki Biam | 09.61 | 07.51 | 13/4/2015 | 25/11/2015 | 227 | 1430 |
| | Katsina Ala | 09.28 | 07.16 | 9/4/2015 | 28/11/2015 | 234 | 1531 |

Table 4. 2014 Seasonal Rainfall Predictions for Benue State, Nigeria (Source: NIMET)

| Year | City | Longitude | Latitude | Onset date | Season end | Season length days | Annual Rainfall (mm) |
|---|---|---|---|---|---|---|---|
| 2014 | Gboko | 09.00 | 07.32 | 1st April | 3rd Dec | 238 | 1579 |
| | Markurdi | 08.54 | 07.73 | 20th April | 22nd Nov | 203 | 1046 |
| | Otukpo | 08.14 | 07.20 | 30th March | 4th Dec | 240 | 1618 |
| | Aliade | 08.48 | 07.30 | 1st April | 3rd Dec | 239 | 1585 |
| | Oju | 07.91 | 07.38 | 2nd April | 3rd Dec | 237 | 1559 |
| | Ugbokpo | 07.88 | 07.66 | 5th April | 30th Nov | 231 | 1472 |
| | Wanunne | 08.89 | 07.57 | 4th April | 1st Dec | 233 | 1499 |
| | Anyiin | 08.58 | 07.71 | 6th April | 30th Nov | 230 | 1457 |
| | Kyado | 09.72 | 07.65 | 5th April | 30th Nov. | 232 | 1475 |
| | Zaki Biam | 09.61 | 07.51 | 3rd April | 1st Dec | 234 | 1518 |
| | Katsina Ala | 09.28 | 07.16 | 30th March | 4th Dec | 241 | 1632 |
| 2013 | Gboko | 07.32 | 09.02 | 23rd April | 10th Nov | 202 | 1000 |
| | Markurdi | 09.00 | 08.00 | 21st April | 17th Nov | 210 | 1189 |
| | Otukpo | 07.18 | 08.13 | 12th April | 16th Nov | 219 | 1217 |
| 2012 | Gboko | 09.02 | 07.32 | 7th April | 11th Nov | 216 | 1422 |
| | Markurdi | 09.00 | 08.00 | 16th April | 11th Nov | 204 | 1227 |
| | Otukpo | 08.13 | 07.18 | 5th April | 11th Nov | 218 | 1466 |
| 2011 | Gboko | 07.32 | 09.02 | 25th April | 6th Nov | 192 | 1009 |
| | Markurdi | 09.00 | 08.00 | 12th April | 9th Nov | 209 | 1242 |
| | Otukpo | 07.18 | 08.13 | 13th April | 9th Nov | 207 | 1209 |

Table 5. Summary of 2011-2015 SRPs in terms of agro-ecological zones (Source: Nigerian Meteorological Agency – NIMET)

| Agro-Ecological Zones | States covered | Onset dates | Cessation Dates | Length of Growing (Planting) Seasons (in days) | Seasonal Rainfall Amount (mm) |
|---|---|---|---|---|---|
| Swamp Forest | Lagos, Bayelsa, Rivers, Akwa Ibom, Cross River, etc | 24 Feb - 30 March | 4 - 11 November | 227 - 266 | 1200 - 2700 |
| Tropical Rain Forest | Ogun, Ondo, Osun, Edo, Imo, Delta, etc | 7 March - 3 April | 3 - 16 November | 220 - 247 | 1200 - 2700 |
| Guinea Savannah | Kwara, Kogi, Niger, Benue, Abuja, Taraba, Oyo, Enugu | 23 March - 2 June | 5 - 12 November | 163 - 233 | 900 - 1700 |
| Sudan Savannah | Bauchi, Yola, Gombe, Kano, Kaduna, Plateau, etc | 9 May - 10 June | 16 Oct - 7 November | 129 - 183 | 800 - 1100 |
| Sahel Savannah | Borno, Sokoto, Zamfara, Katsina, Kebbi, Adamawa | 15 June - 30 June | 3 - 22 October | 93 - 150 | 300 - 800 |

In a bid to provide an aggregate view of the impact of global warming and El Nino on rainfall as an important weather and climate variable for the study period of 2011-2015, Table 5 shows the summary of the 2011-2015 SRPs in terms of Agro-Ecological zones in Nigeria.

The data show decreasing rainfall from the Swamp Forest region of Nigeria to the Sahel Savannah region; a reflection of the growing impact of desertification on Northern Nigeria. The Adum-Aiona Community is in the Guinea Savannah region with SRP of 900-1700 mm. Overtime, the data indicates that the onset dates are becoming late while the cessation dates are getting early, all pointing to the growing influence of climate vagaries on the environment. To survive, mitigation and acclimatization techniques are required by the rural farmers in Adum-Aiona just as in other rural African communities.

The data is a confirmation that human impacts such as deforestation, fossil fuel burning, among others account for carbon dioxide emission into the atmosphere that in turn result in climate change harsh conditions such as late onset and early cessation of rains, flash flooding, gully erosion, coastal erosion, caked soil, loose of soil nutrients, just to mention a few. The resultant effect is depletion in agricultural yield with dire implications for food insufficiency and insecurity, hunger, social tensions, unemployment, kidnapping and terrorism.

The proposed Climate Change Response System (CCRS) is promising for re-orientating rural dwellers on ecologically-friendly behaviours such as afforestation, discouraging bush burning practices, and use of clean energy for cooking. It also facilitates the ability of rural dwellers to adjust to weather and climate vagaries as well as mitigate their negative impacts by embracing climate-resilient agriculture. CCRS relies on its creative art-modelled sensitization campaign sub-system for achieving the trio of environmentally-friendly behaviours, adaptation and mitigation strategies. The use cases (tasks) of CCRS are mechanisms that reposition rural African dwellers for bracing up to the realities of climate unpredictability: Sensitization and education of farmers, for example, will not only promote environment-friendly behaviours but will teach them adaptation and mitigation techniques; the climate change insurance policy will encourage the introduction and implementation of weather insurance policy to safeguard against climate change-related agricultural losses; Dams and river basins revitalization will harness surface water for irrigation farming as complement of rain-fed agriculture; Harnessing of underground water through digging of community wells and boreholes will augment traditional techniques for adaptation and mitigation, hence promoting domestication and ownership of CCRS; Extension services will ensure that farmers are enlightened on climate-resilient agricultural practices and inputs; Packaging and dissemination of meteorological forecasts through formal institutions (extension services) and informal institutions (worship places, town hall meetings, and age-grade group meetings, among others) will promote proactive actions by farmers and all stakeholders in combating the menace of climate change.

*4.2. Evaluation Threats*

It is not impossible that an expanded evaluation of the respective modules of the CCRS could unveil fresh dimension of the impact of global warming and El Nino on rural African communities like the Adum-Aiona community. In any case, the seasonal rainfall prediction data used for our evaluation of the existential threat posed by climate change to human livelihoods are real-life operational data obtained from the Nigerian Meteorological Agency (NIMET). NIMET over the years have built sufficient capacity in availing climate, weather, and water information for safety and sustainable development which encompasses information of expected rainfall pattern that is valuable for planning, decision making and execution of socio-economic development projects. As a result, they can make objective annual

prediction that impact various sectors such as agriculture, aviation, transportation, water resources, telecommunication, and construction, among others. Hence, NIMET's views can be taken seriously (Host et al., 2000; Runeson, 2003; Sauro, Kindlund, 2005; Svahnberg et al., 2008). In addition, only 5-year seasonal rainfall predictions were used in the assessment, which has the potential of constraining the statistical significance of study findings (Nielsen, Landauer, 1993; Turner et al., 2006). In any case, the outcome of the survey is indicative that the combined effects of global warming and El Nino have impacted significantly on rainfall patterns in Africa and rural Africa in particular with evidence of early cessation and late onset of rains. This underscores the need for updated adaptation and mitigation techniques for Africans to survive environments imposed by climate change. In our view, this is a significant result since at this juncture in the study, the key objective is to secure an impression of the impact of climate change on livelihoods in rural Africa and how a climate change response system can aid adaptation and mitigation. Hence, in spite of the limited seasonal rainfall prediction data used in the evaluation, there is sufficient ground to infer that climate vagaries affects human livelihoods and a response system for climate change has the potential to strengthen adaptation and mitigation. We can thus generalize that the model-driven climate change response system is effective for instituting ecologically friendly behaviors and driving climate-resilient means of livelihood among both rural and urban African folks.

## 5. Recommendations

To cushion the challenge of climate change, CCRS is inbuilt with mechanisms for behaviour change, adaptation and mitigation. With these measures, it is hoped that the adverse impact of El Nino as expressed in unfavourable temperatures and rainfall will be reduced. Based on the study outcome, we advise that the following measures be put in place to help rural African dwellers to cope with the negative impact of climate vagaries on livelihoods:

1. Sustained sensitization and education of rural dwellers on dangers of environmentally unfriendly activities such as deforestation and indiscriminate burning of fossil fuel as exemplified in the Creative arts model. Formal method (extension services) and informal methods (worship places, age groups, town hall meetings, etc.) could be harnessed.
2. Extension services should be revamped at all levels of government to reach out to farmers with latest information on new farming techniques and inputs that promotes climate-resilient agriculture.
3. In the light of established agricultural impact of climate vagaries, the scope of extension services should be expanded to include seasonal rainfall predictions (SRPs) by meteorological agencies. The SRP information will guide farmers in decision making.
4. There is need for agricultural policy consistency particularly with respect to construction and maintenance of dams and river basins for irrigated farming to complement the dominant rain-fed agriculture in Africa.
5. The various traditional approaches adopted by locals in the past for adapting and reducing climate change impact should be integrated in any climate change response system for communities to domesticate and take ownership of such system.
6. Government and the private sector should start thinking of implementing climate change insurance policy as safety net for those who may suffer agricultural loses as a result of the weather vagaries.
7. Appropriate pricing for kerosene, cooking gas, and petrol should take into account the purchasing power of the rural poor. This way, alternative to the use of firewood is formulated, discouraging deforestation and strengthening afforestation drive.

## 6. Conclusion

We have provided both computational and artistic impressions of the effect of El Nino and climate vagaries on rural Africa using the Adum-Aiona community as case study. In the face of growing impact of El Nino on livelihoods of rural Africans, measures to promote afforestation, shift to clean energy and climate-resilient agriculture and construction cannot be overemphasized. El Niño gives rise to global changes in rainfall and temperatures. Simulations and measurements have shown that climate change is contributing to extreme El Niños in recent years with visible impact on human lives as evident in humanitarian crisis in the horns of Africa – Ethiopia and Eritrea. It confirms the sentiment that the most affected are developing countries bordering the Pacific Ocean whose means of livelihood are agriculture and fishing. This study has provided empirical evidence to the effect that climate change threats on man and his means of livelihood are real. The study equally designed a climate change response system for aiding climate change adaptation and mitigation. We concluded by recommending a number of measures that will promote ecologically friendly behaviours and protect rural African dwellers from the negative impacts of climate change. Future research is needed to institute and strengthen weather-conscious insurance policy for African farmers as a mitigation strategy for climate-induced loss of agricultural products.

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## References


1. AKANDE V., 2016, *Calabar Carnival 2016 to Explore Climate Change Again*, http://thenationonlineng.net/calabar-carnival-2016-to-explore-climate-change-again (15.04.2016).
2. BABATUNDE H.O., 2007, *A Comprehensive Approach to Visual and Creative Arts*, Agege, Lagos, HOB Designs Nig. Limited, p. 9.
3. BARBIER G., CUCCHI V., HILL R.C.D., 2015, Model-driven engineering applied to crop modeling, in: *Ecol. Informatics* 26, p. 173-181.
4. BELLPRAT et al., 2015, Unusual past dry and wet rainy seasons over Southern Africa and South America from a climate perspective, in: *Weather and Climate Extremes* 9, p. 36-46.
5. BRAMBILLA M., FRATERNALI P., 2014. Large-scale Model-Driven Engineering of web user interaction: The WebML and WebRatio experience, in: *Science of Computer Programming* 89, p. 71-78.
6. BRUNELIERE H. et al., 2014, MoDisco: A model driven reverse engineering framework, in: *Information and Software Technology* 56, p. 1012-1032.
7. BUBECK A., MAIDEL B., LOPEZ F.G., 2014, Model driven engineering for the implementation of user roles in industrial service robot applications, in: *Proc. Technology* 15, p. 605-612.
8. CALATAYUD et al., 2016, Can climate-driven change influence silicon assimilation by cereals and hence the distribution of lepidopteran stem borers in East Africa?, in: *Agriculture, Ecosystems and Environment* 224, p. 95-103.
9. CALEGARI D., MOSSAKOWSKI T., SZASZ N., 2016, Heterogeneous verification in the context of model driven engineering, in: *Science of Computer Programming* p. 1-33.
10. CALZADILLA A.,, ZHU T., REHDANZ K., ehdanz, TOL R.S.J., RINGLER C., 2014, Climate change and agriculture: Impacts and adaptation options in South Africa, in: *Water Resources and Economics* 5, p. 24-48.
11. CERVERA et al., 2015, On the usefulness and ease of use of a model-driven Method Engineering approach, in: *Informat. Systems* 50, p. 36-50.
12. CHABRIDON S. et al., 2013, Building ubiquitous QoC-aware applications through model-driven software engineering. *Science of Computer Programming* 78, p. 1912-1929.
13. CHIDIEBERE O., CHIRWA P.W., FRANCIS J., BABALOLA F.D., 2016, Assessing forest-based rural communities' adaptive capacity and coping strategies for climate variability and change: The case of Vhembe district in South Africa, in: *Environmental Development*.
14. CHINOWSKY P., SCHWEIKERT A., HAY-LES C., 2014, Potential Impact of Climate Change on Municipal Buildings in South Africa, in: *Proc. Econ. and Finance* 18, p. 456-464.
15. CICCOZZI F., CICCHETTI A., SJODIN M., 2013, Round-trip support for extra-functional property management in model-driven engineering of embedded systems, in: *Information and Software Technology* 55, p. 1085-1100.
16. CUADRADO J.S. et al., 2014, Applying model-driven engineering in small software enterprises, in: *Science of Computer Programming* 89, p. 176-198.
17. CLARKE et al., 2016, Climatic changes and social transformations in the Near East and North Africa during the 'long' 4th millennium BC: A comparative study of environmental and archaeological evidence, in: *Quaternary Science Reviews* 136, p. 96-121.
18. DAVIES et al., 2014, The CancerGrid experience: Metadata-based model-driven engineering for clinical trials, in: *Science of Computer Programming* 89, p. 126-143.
19. DAVIES et al., 2015, Formal model-driven engineering of critical information systems, in: *Science of Computer Programming* 103, p. 88-113.
20. FANT C., SCHLOSSER A., STRZEPEK K., 2016, The impact of climate change on wind and solar resources in southern Africa, in: *Applied Energy* 161, p. 556-564.
21. GARCIA-MAGARINO G. PALACIOS-NAVARRO, 2016, A model-driven approach for constructing ambient assisted-living multi-agent systems customized for Parkinson patients, in: *The Journal of Systems and Software* 111, p. 34-48.
22. GORTON I., 2011, *Essential Software Architecture*. Springer.
23. GRACE et al., 2015, Linking climate change and health outcomes: Examining the relationship between temperature, precipitation and birth weight in Africa, in: *Global Environmental Change* 35, p. 125-137.
24. GURUNULE D., NASHIPUDIMATH M., 2015, *Analysis of Aspect Orientation and Model Driven Engineering for Code* Generation, in: Procedia Computer Science 45, p. 852-861.
25. HOST M., REGNELL B., WOHLIN C., 2000, Using students as subjects - a comparative study of students and professionals in lead-time impact assessment, in: *Empirical Software Engineering* 5(3), p. 201-214.
26. HUTCHINSON J., WHITTLE J., ROUNCEFIELD M., 2014, Model-driven engineering practices in industry: Social, organizational and managerial factors that lead to success or failure, in: *Science of Computer Programming* 89, p. 144-161.
27. JONES M.R., SINGELS A., RUANE A.C., 2015, Simulated impacts of climate change on water use and yield of irrigated sugarcane in South Africa, in: *Agricultural Systems* 139, p. 260-270.
28. KAHSAY G.A, HANSEN L.G., 2016, The effect of climate change and adaptation policy on agricultural production in Eastern Africa, in: *Ecological Economics* 121, p. 54-64.
29. KLAUSBRUCKER et. al, 2016, A policy review of synergies and trade-offs in South African climate change mitigation and air pollution control strategies, in: *Environmental Science & Policy* 57, p. 70-78.

30. KUSANGAYAS. et al., 2014, Impacts of climate change on water resources in southern Africa: A review, in: *Physics and Chemistry of the Earth* 67/69, p. 47-54.
31. LI et al., 2015, Hydrological projections under climate change in the near future by RegCM4 in Southern Africa using a large-scale hydrological model, in: *Journal of Hydrology* 528, p. 1-16.
32. LIM S. et al., 2016, 50,000 years of vegetation and climate change in the southern Namib Desert, Pella, South Africa, in: *Palaeogeography, Palaeoclimatology, Palaeoecology* 451, p. 197-209.
33. LUKMAN T. et al., 2013, Model-driven engineering of process control software – beyond device-centric abstractions, in*: Control Engineering Practice* 21, p. 1078-1096.
34. LUTJEN M. et al., 2014, Model-driven logistics engineering – challenges of model and object transformation, in: Procedia Technology 15, p. 303-312. 15, p. 303-312.
35. MARTINEZ-GARCIA et al., 2015, Working with the HL7 metamodel in a Model Driven Engineering context, in: *Journal of Biomedical Informatics* 57, p. 415-424.
36. MOYO E.N., SHINGIRAI S., 2015, Southern Africa's 2012-13 Violent Storms: Role of Climate Change, in: *Procedia IUTAM* 17, p. 69-78.
37. NIELSEN J., LANDAUER T., 1993, A mathematical model of the finding of usability problems, in: *Proceedings of ACM INTERCHI'93 Conference*, p. 206-213.
38. PANESAR-WALAWEGE R.K., SABETZADEH M., BRIAND L., 2013, Supporting the verification of compliance to safety standards via model-driven engineering: Approach, tool-support and empirical validation, in: *Information and Software Technology* 55, p. 836-864.
39. PEREZ et al., 2015, How resilient are farming households and communities to a changing climate in Africa? A gender-based perspective, in: *Global Environmental Change* 34, p. 95-107.
40. RALEIGH C., CHOI H.J., KNIVETON D., 2015, The devil is in the details: An investigation of the relationships between conflict, food price and climate across Africa, in: *Global Environmental Change* 32, p. 187-199.
41. RIESENFELD R.F., HAIMES R., COHEN E., 2015, Initiating a CAD renaissance: Multidisciplinary analysis driven design Framework for a new generation of advanced computational design, engineering and manufacturing environments, in: *Comput. Methods Appl. Mech. Engrg.* 284, p. 1054-1072.
42. RUNESON P., 2003, Using students as Experiment Subjects – An Analysis on Graduate and Freshmen Student Data, in: (ed.) Linkman S., 7th International Conference on Empirical Assessment & Evaluation in Software Engineering (EASE'03), p. 95-102.
43. RUTLE A. et al., 2015, Model-Driven Software Engineering in Practice: a Content Analysis Software for Health Reform Agreements, in: *Procedia Computer Science* 63, p. 545-552.
44. SCHROTH G. et al., 2016, Vulnerability to climate change of cocoa in West Africa: Patterns, opportunities and limits to adaptation, in: *Science of the Total Environment* 556, p. 231-241.
45. SAURO J., KINDLUND E., 2005, A Method to Standardize Usability Metrics into a Single Score, in: *Proceedings of ACM SIGCHI Conference on Human Factors in Computing Systems*, ACM, p. 401-409.
46. SEO S.N., 2014. Evaluation of the Agro-Ecological Zone methods for the study of climate change with micro farming decisions in sub-Saharan Africa, in: *Europ. J. Agr.* 52, p. 157-165.
47. Da SILVA R., 2015, Model-driven engineering: A survey supported by the unified conceptual model, in: *Computer Languages, Systems & Structures* 43, p. 139-155.
48. SIROHI N., PARASHAR A., 2013, Component Based System and Testing Techniques, in *Advanced Research in Computer and Communication Engineering*, 2(6), p. 33-42.
49. STEYNOR et al., 2016, Co-exploratory climate risk workshops: Experiences from urban Africa, in: *Climate Risk Management*.
50. SVAHNBERG M., AURUM A., WOHLIN C., 2008, Using students as Subjects -An Empirical Evaluation, in: *Proc. 2nd International Symposium on Empirical Software Engineering and Management ACM*, p. 288-290
51. TURNER C.W., LEWIS J.R., NIELSEN J., 2006, Determining usability test sample size, in: (ed.) Karwowski W., *International Encyclopaedia of Ergonomics and Human Factors*, CRC Press, Boca Raton, p. 3084-3088.
52. WAUTELET Y., KOLP M., 2016, Business and model-driven development of BDI multi-agent system, in: *Neurocomputing* 182, p. 304-321.
53. WEBBER H., GAISER T., EWERT F., 2014, What role can crop models play in supporting climate change adaptation decisions to enhance food security in Sub-Saharan Africa?, in: *Agricultural Systems* 127, p. 161-177.
54. WEHRMEISTER et al., 2014, Combining aspects and object-orientation in model-driven engineering for distributed industrial mechatronics systems, in: *Mechatronics* 24, p. 844-865.
55. van WESENBEECK C.F.A., 2016, Localization and characterization of populations vulnerable to climate change: Two case studies in Sub-Saharan Africa, in: *Appl. Geogr.* 66, p. 81-91.
56. WUNDSCH M. et al., 2016, Sea level and climate change at the southern Cape coast, South Africa, in: *Palaeogeography, Palaeoclimatology, Palaeoecology* 446, p. 295-307.
57. YOUNG A.J. et al. 2016, Biodiversity and climate change: Risks to dwarf succulents in Southern Africa, in: *J. of Ar. Env.*129, p. 16-24.
58. ZINYENGERE N., CRESPO O., HACHIGONTAS., 2013, Crop response to climate change in southern Africa, in: *Global and Planetary Change* 111, p. 118-126.

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# Sustainable Development in the Context of the Integral Approach of the Human Person Guido Gatti

# Zrównoważony rozwój w kontekście moralnego ujęcia osoby ludzkiej Guido Gattiego

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## Abstract
In the proposed article we undertook the analysis of the question connected with the idea of moral personality in the study by Guido Gatti and its correlation with the sustainable development. The fundamental element of our research was to indicate that there is an interdependence between the dynamics of moral development and moral personality which, in consequence, leads to the idea of sustainable development as a condition *sine qua non* of the order in the life of man.

**Key words:** Guido Gatti, moral personality, moral person, education

## Streszczenie
W proponowanym artykule pojęliśmy analizę zagadnienia związanego z koncepcją osobowości moralnej w badaniach Guido Gattiego i jej korelacji ze zrównoważonym rozwojem. Podstawowym elementem naszych poszukiwań było wskazanie, iż istnieje zależność między dynamiką rozwoju moralnego a osobowością moralną, co w konsekwencji prowadzi do idei zrównoważonego rozwoju jako warunku *sine qua non* porządku w życiu człowieka.

**Słowa kluczowe: Guido** Gatti, osobowość moralna, osoba moralna, wychowanie

### Introduction

The dynamics of individuals in the context of moral development observed by different researchers dealing with ethics, axiology, deontology or education, shows a multidimensional model of changes in the sphere of social behaviors. The integral part of human existence is ethical-moral development which is not so much a phenomenon but the source of building sustainable development in different spheres of social life (Bartoszewski, 2015).
Obviously, it all depends on accepted anthropological concepts which result in legal and social norms, as well as economic or environmental consequences. Hence, it is always a challenge to approach the question so as to comprehensively and at the same time logically describe the process of human development, as well as education to become sustainably integrated with the animate and inanimate world.
The task set by Gatti led him in the direction of presenting his view of the person development, and, at the same time, moral education (Solarski, 2013). In this way, basic issues of this article come up, so in the first place, it is to depict the purposefulness of the developmental process of human individuals itself, because without this analysis it would be difficult to

take on the issue of sustainable development. It is also necessary to pay attention to the fact that personality integration takes place in the process of socialization and education, it was perfectly highlighted by Gatti who indicated, that without this element there is no moral-ethical growth in individuals' lives. Therefore, personality development is the basic assumption of educational view of moral growth of an individual and, hence, sustainable development.

In the article we will present possibly comprehensive picture of the before mentioned issues in Gatti's approach. These assumptions are the condition to correctly understand the idea of sustainable development in social, local, family and individual life.

**The perspective of moral development and sustainable development**

Theological-moral approach to Guido Gatti human person directs the so called structuring of morally integrated personality The basic perspective of this approach is:

a) Autonomy,
b) Rationality,
c) Altruism.

These three elements become the condition *sine qua non* of mature moral personality, in this way they set the goal which is aiming for the full relationship with the reality of animate and inanimate world. Gatti's view is not the only reflection of biblical-theological understanding of the universe, that is macrocosm and microcosm, but it also finds its reflection in developmental theories for example by: Piaget, Eysenk, Jung and Adler.

The first fundamental direction of development is transition from initial heteronomy, that is immaturity of individuals to moral autonomy (Gatti, 1983, 1992). Here, it must be stressed that it is not about autonomies in the context of distance from Aristotelian-Thomist question of truth, which does not eliminate the aspect connected with the relationship between freedom and conscience. Taking on such an assumption leads to recognition of moral experience as the source of human development. Therefore, heteronomy is nothing else but the theological approach to the world of human existence, so man at the beginning of life undergoing socialization and education confronts good and evil, and the choice must be conditioned not so much by the consensus or dialogicality, but by good relating to objective truth. What is more, the choice must not be determined by desire, because it eliminates the freedom of choice. If it is so, then the motivations of specific deeds cannot be recognized as right resulting from coherent personality, because they are generated by desire, for example financial means. This factor of misinterpretation and justification of utilitarian behavior is connected with, on the one hand, disfunctional behavior rejecting the relationship *choice – conscience*, and on the other hand, the biblical reference *(be fruitful, and multiply, and replenish the earth) and subdue it*. Because of that, Gatti postulates that in the world of human existence we should return to morality of the natural and eternal law and not of the civil law. Natural law, which has its source in eternal law implicates the idea of sustainable development. The world of nature, which in Gatti's opinion is *Signum Dei*, shows us how to realise moral education to keep balance on the level of one's own being and the beings of nature.

In case of determinants – utilitarianism, desire for profits, lack of coherence of actions and deeds – and the lack of interiorized balance of the world, and in this case sustainable development, a person is perforce not so much internally torn but disintegrated, and only after showing information he or she tries to integrate in himself/herself the principle reinforced in the process of education, for example, moral utilitarianism with the principle of the idea of sustainable development, which in consequence leads to the creation of illusory moral – ethical solutions. Gatti, as Solarski indicates, claims that even if such an immature man tries to do good , he or she cannot define himself or herself as good because he/she does not love good and does not understand its rights and values. The internal conflict comes from the fact that the particular person id different from what he or she does (Solarski, 2013).

The full autonomy therefore emerges in the maturity of man and is connected with responsible freedom, so a man does good, or in other words behaves morally, not because it is imposed by positive law, but is obedient to interiorized values, which he or she accepts as the truth reinforced by conscience, which is not the echo of delusional voices but the voice of his or her inside and the expression of his or her maturity and responsibility for himself or herself and for the surrounding reality of the existing world (Gatti, 1985), so the full autonomy is gaining unity between internal goodness and the goodness of individual choices and actions (Solarski, 2013). Therefore, in the subject not of discord but between the utilitarian principles and values included in the idea of sustainable development.

This perspective, directed at autonomy, has for the Italian researcher educational significance stating that education leads to the liberation of human beings from heteronomy, and at the same time leads to internal unity.

Another significant determinant of the full moral personality is rationality defined as the ability to build a dialogue of norms and principles compatible with the natural law and eternal law (Slosiar, 2015). At the same time, it indicates that the development of personality takes place in the processes of social, parental and institutional interaction.

Talking of rationality, it is impossible to ignore the basic fundamentals of understanding the word rationality itself. According to Gatti, the concept can-

not be analyzed without referring to ethical – moral principles, and at the same time the truth, because it leads to relativisation of human and natural reality. As a consequence, we can adopt each event connected with economy, education, environment to our subjective needs without taking into account the laws of nature: natural and eternal law (Gatti, 1994). Accepting such a state of things, Gatti remains consistent with educational system by Jan Bosco, who indicated that the fundamental role in shaping individual's personality is played by:

a) Reason,
b) Religion (in universal meaning),
c) Amorevolezza (fondness, tenderness).

This standpoint leads him to the definition of rejecting the balance in the world as the evil in itself that is *intrinsece malum*, which should be understood as irrational approach to the laws of nature and the eternal law and accepting criteria of the so called order rationality (Gatti, 1988, 1994), that is established. As a result, the deed, action, decision is conditioned by for example: utilitarianism, pragmatism or materialism.

Professor emphasizes that understanding these principles – connected with rationality – requires the right approach who a human person is and what role he or she plays in the world. That is why, it is necessary to look for ideas which will implement sustainable development between what is conscious and this which does not have this consciousness.

Otherwise , we will have the so called infantile morality called expedient morality.

This morality appears in opportunistic actions having no consideration for the people, environment, animals or the natural resources. That is why, it calls for education based on rationality, which requires such factors as:

a) Trust,
b) Reasoning,
c) Referring to intelligence,
d) Basing on the so called objective truth (in this case, Aristotelian-Thomist).

The creativity that rationality allows is the very ability to solve problems, looking for strategies and innovative solutions, without negating universal moral values (Solarski, 2013).

The third and the final element of the perspective of moral development is the successful transition from egocentricity to altruism. Here, Gatti, following Kohlberg, indicates that the fundamental element is cognitive development. It is not about the reduction on the cognitive level, but about showing the developmental process of man. Therefore, in his opinion, the way to altruism leads through autonomy, rationality to fully manifest human personality in altruism. Altruism cannot be divided nor graded, although in contemporary world it often occurs in the form of:

a) Pro-social behaviors – they are characterized by unilateral submission to authority, for example: *political celebrity*,
b) Philanthropy – this stage is characterized by cooperation in the form of sharing for example financial means,
c) Voluntary service – at this stage an individual assumes duties with the assumption of getting profit, for example: professional experience.

In these stages one can see mutual benefit, where postconventional aware man revises the legal order not for the sake of the good connected with the sustainable development, but for his or her personal gain.

Obviously, we should not approach the above graded concept of altruism one-sidedly, because not all behaviors are motivated in utilitarian way. It often happens that qualifying an individual to a particular group without proper analysis results in making a mistake of type: *pars pro toto*. Altruism is constituted by activities resulting from interiorized laws, values.

Therefore, behavior which is based on general positive view of the world and other people, on responsibility, kindness and love for others (Solarski, 2003) indicates empathy, which in consequence allows positive attitude towards the animate and inanimate world. Basing on this, it is necessary to state that altruism is a positive feature, the effect of good education.

## Moral personality as a subject of education and the idea of sustainable development

Discussing the question of education in the context of shaping personality we cannot ignore the structure of understanding personality by Gatti. Contemporary psychology, as a theoretical and empirical science, does not offer an explicit answer to the question what personality is. Here, we cannot omit various concepts adopted by researchers such as Freud, Piaget, Frankl or Allport, Cattel, Bandura and Mischel (Pervin, John, 2001). What seems to be common, in all concepts, is the fact that personality is a unique, individual, nomadic element of human being.

Therefore, psychologists describe this structure having in mind the adopted key closing in anthropology and psychopathology, in other words, they indicate what the source of human development is and alternatively his or her anomalous features. Not seldom, the source of adopted assumptions was referring to philosophy, sociology and natural sciences as places for considering the issue of personality (Oleś, 2005). Being aware of this heterogenous knowledge, Gatti dealswith these issues in view of their significance in understanding moral development and moral education. Also he does not try to clearly define personality, but he presents it in descriptive way, emphasizing, above other things, its individual elements – as it seems – chosen or confirmed in the before mentioned developmental theories (Solarski, 2013).

In Gatti's opinion, personality is nothing else but the result of the factors that form it. Not without difficulty can we observe that Gatti's analysis goes in the direction of describing personality in the context of freedom and responsibility as well as ethical approach to natural reality. For him, the three elements are significant in terms of studies of the essence of human existence. This element is also recognized in the idea of sustainable development (Mulia, Behura, Kar, 2016).

Therefore, our author understands personality dynamically, which is constituted from various coherent components. The first element is *corpus biologica,* that is man is a bodily being. So not only does he/she own a body, but he/she is a body. However, this element is not a determinant in existence. Another partial component of human personality is the unity of primal drives *ens per se* (Gatti, 1988, 1994). The drives can be sublimated, they give energy to act in the form of accepting civic attitude, pro – natural or pro – social. The third link of moral personality is trust, discussed extensively by Erikson (Gatti, 1994). Trust generates faith on which an individual is based and authenticates himself or herself as the essence of moral activities. Here, we can notice similarity to the theory by L. Kohlberg who indicated that only taking into account objective morality, can we realise our full potential as human beings, so it is worth being just in the world of injustice. The fourth element of formed moral personality is in Freud's *ego – force*, that is:

a) Clearmindedness
b) Rational knowledge
c) Realistic interpretation of the world
d) Avoiding judgement
e) Ability to communicate with others,

Therefore, *ego – force* which is subjected to educational and self-educational influence leads to the full personality of an individual, with keeping at the same time elements such as:

a) *Corpus biologica*,
b) Drives,
c) Trust.

These aspects of moral personality lead an individual to adopting, speaking in Gatti's language, the culture of a person, understood as the world of symbolism shaped by language, art, technology, norms of social life and reflection (Gatti, 1994, 1997). The culture of a person conditions significantly moral life affecting the constitution of moral personality, manifesting itself in care of the world in which the person happens to live. In this way, it introduces balance, which in consequence leads to educational activities, by means of which a person develops himself/herself, his/her relationship with micro – and macro – society, environment, vegetation, natural resources and animals.

The picture of the development of moral personality leads to the idea of sustainable development (Sarzała, 2013), as the complex world is on various levels of awareness of an individual and cognitive dimensions connected with knowledge and moral insight. This moral insight takes place in conscience shaped in educational processes.

In this way, Gatti completes his own concept of understanding the structure of moral personality in responsibility, reaching in consequence the definitive and the most determinative part of his studies, namely freedom (Gatti, 1981, 1983, 1985).

The presence of freedom in the structure of moral personality is the place of conscious choice of common good with keeping the imperative of conscience. Freedom is incorporated in the structure of personality, and, because of this, the past lives in the presence, shaping and conditioning social activities, individual for future generations, so each free choice is nothing else but the driving force of a certain sequence of events. For sustainable development, it is proper education for responsible and free management of common good which is the Earth.

Gatti's project assumes development, but characterized by moral engagement, which – being vertical typology – indicates the sequence of developmental stages of an individual for common and sustainable good. In this place it is necessary to specify five types of character negating sustainable good, these are characters:

a) Amoral,
b) Opportunistic,
c) Conformist,
d) Irrational,
e) Altruistically – utilitarian (Gatti, 1995).

This typology is valuable for its engagement in moral life. What is more, such a view of verification of educational strategies only in the processes of bringing the idea of sustainable development to awareness.

Therefore, Gatti rightly tries to convince that in the structure of moral personality there are visible different dimensions and constitutive elements which cannot be reduced to a blurry theory of development, such as in Freud or analytical psychologists (Gatti, 2003, 2008).

The proper structure of moral personality leads to responsible actions for the development of individuals both *hic et nunc* as well as in the past. This in consequence leads to the acceptance of free and empatihc management of the earthly goods for future generations.

## Conclusion

In Gatti's view we have the so called laws of gradual development, which are shared by each human being. What is more, the laws can serve theoreticians dealing with educational reality, and, at the same time, they may serve those who are looking for the-

oretical justification of their ideas in this and the idea of sustainable development.

Knowledge of man and everyday experience leave no doubt about the fact that Gatti's dynamics of moral growth has its stages which appear in the processes of *social – cultural – economical* interaction. This truth has a crucial meaning, as it leads us to realise, that moral education of a human being affects the future of our children and their children, and so on. It requires from us adjusting educational activities to the plausibility of understanding what the world in which we live is and the consequences of overexploitation for human kind. Furthermore, shaping or forming is to guide us to the so called moral personality, which was described by Gatti in the context of moral theology.

**References**


1. BARTOSZEWSKI J., 2015, Dynamiz edukacji i wychowania w ujęciu Guido Gattiego, in: *Współczesne trendy w edukacji dziecka, eds.* Styczyńska, M., M. Olejniczak, M., PWSZ Konin, Konin.
2. GATTI G., 1983, *L'educazione morale e l'educazione alla fede: metodologia pastorale speciale,* Lummann, Roma.
3. GATTI G., 1981, *Morale cristiana e realtà economica*, Leumann, Torino.
4. GATTI G., 1983, *L'educazione morale e l'educazione alla fede: metodologia pastorale speciale*, Lummann, Roma.
5. GATTI G., 1985, *Educazione morale etica cristiana,* Leumann, Torino.
6. GATTI G.,1988, *Morale sessuale, educazione dell'amore,* Leumann, Torino.
7. GATTI G., 1988, *Temi di morale fondamentale*, Leumann, Torino.
8. GATTI G., 1992, *Il dramma come forma di discorso etico*, Leumann, Torino.
9. GATTI G., 1994, *Educazione morale etica cristiana*, Leumann, Torino.
10. GATTI G., 1997, *Libertà e legge,* Leumann, Torino.
11. GATTI G., 1997, *Questioni di etica dell'economia*, Lummann, Roma.
12. GATTI G., 2003, *Manuale di teologia morale,* Leumann, Torino.
13. GATTI G., 2008, *Etica della comunicazione,* Lumann, Roma.
14. MULIA P., BEHURA A.K., KAR S., 2016, Categorical Imperative in Defense of Strong Sustainability, in: *Problemy Ekorozwoju/ Problems of Sustainable Development*, vol. 11, no 2, p. 29-36.
15. OLEŚ P.K., 2005, *Wprowadzenie do psychologii osobowości*, Warszawa.
16. PERVIN L.A., JOHN O.P., 2001, *Personality: theory and research*, John Wiley & Sons, New York.
17. SOLARSKI P., 2003, *Wychowanie moralne w ujęciu Guido Gattiego*, Wyd. KUL, Lublin.
18. SLOSIAR J., 2015, Identita a osamelosť človeka v súčasných sociálno-ekonomických podmienkach, in: *KSSE* vol. 1, no 3, p. 207-224.
19. SZARZAŁA D., 2013, Rodzina jako środowisko kształtujące postawy prospołeczne, in: *Zeszyty Naukowe GSW*, no 13, p. 349-363.

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# Influence of RES Integrated Systems on Energy Supply Improvement and Risks

# Wpływ zintegrowanych systemów OZE na zaopatrzenie w energię – aspekty pozytywne i ryzyka

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## Abstract

RES (renewable energy sources) plays a very important role in the context of sustainable development, as an alternative to fossil fuels and nuclear power.

This paper presents the description of a RES technology cluster – an integrated system, which consists of equipment using different types of RES. It demonstrates that the stochasticity of renewable energy input influences the energy supply reliability. The work considers the influence of diversification of different RES sources on the improvement of energy supply reliability and reduction of risks connected with energy loss. Based on mathematical simulation using the convex optimization method, the authors propose a novelty solution to determine the most effective equipment configuration of an integrated energy system – a RES cluster. Effective computer programs have been developed and registered in order to calculate the optimal integrated renewable energy system in the Russian Federation.

The optimization criterion is the minimal cost of generating 1kWh of electricity of the whole complex of renewable energy sources. The feature of calculating the optimal combination of renewable energy sources is based on the variance of random variables, climatic characteristics unlike average for the year. This approach improves the accuracy of calculations by 25-40%. This leads to a reduction in capital equipment costs and reducing the cost of production of 1kWh of electricity.

**Key words:** renewable energy sources, RES technology cluster, renewable power supply system, energy supply reliability

## Streszczenie

OZE (odnawialne źródła energii) odgrywają istotną role w kontekście rozwoju zrównoważonego, jako alternatywę dla spalania paliw kopalnych i energetyki jądrowej.

W tym artykule opisano klaster technologiczny OZE – zintegrowany system, na który składają się urządzenia wykorzystujące różne rodzaje OZE. Pokazuje, że nieprzewidywalność dostaw energii odnawialnej ma wpływ na niezawodność dostaw energii. Rozważono wpływ dywersyfikacji OZE na poprawę jakości systemu zasilania i zmniejszenie ryzyka związanego ze stratami energii. W oparciu o symulację matematyczną autorzy proponują innowacyjne rozwiązanie pozwalające określić najbardziej efektywną konfigurację sprzętową zintegrowanego systemu energetycznego – klaster OZE. Opracowano i zarejestrowano programy komputerowe umożliwiające obliczenie zintegrowanego systemu energetycznego na przykładzie Federacji Rosyjskiej.

Za kryterium optymizacji przyjęto minimalny kost wytwarzania 1 kWh energii elektrycznej przez cały system odnawialnych źródeł energii. Obliczenia odnoszącej się do optymalnej kombinacji odnawialnych źródełe energii oparte są na wariancji zmiennych losowych i dokładnych danych odnoszących się do warunków klimatycznych (a więc uwzględniono o wiele więcej, niż średnie dane dla danego roku). Takie podejście pozwala na zwiększenie

dokładności obliczeń I 25-40%. W konsekwencji instalacja będzie mniejsza i lepiej dostosowana do potrzeb, co pozwoli na obniżenie ceny wytwarzania 1kWh energii elektrycznej.

**Słowa kluczowe:** odnawialne źródła energii, klaster technologiczny OZE, odnawialny system zasilania, niezawodność systemu zasilania

## 1. Introduction

Sustainable development is a strategy that is concentrated on satisfying basic human needs, both of present and future generations (WCED, 1987). Among them energy issues are especially important, since our civilization cannot function without acquiring energy, in particular electricity. Because of the pollution connected with burning fossil fuels, and fears related to nuclear power renewable sources of energy (RES) seems to be a real alternative. They amounts up to 7-20 % of annual energy production in the developed and developing countries. In the Russian Federation, where the reserves of hydrocarbon are considerable, this index reached the level of 1.2 % in 2014 (excluding Crimea).

Existence of distant settlements and autonomous objects situated throughout the vast territories of the Russian Federation demand reliable independent energy sources. This problem is currently solved mainly by means of diesel generator units powered by the organic fuel. The features of the country's geographical location (middle and high latitudes, severe continental climate, isolated location of the major part of the settled land from seas) induce low-energy wind (3-5 m/s) and relatively low average annual insolation (120-200 W/m$^2$) on the larger part of the Russian Federation. These factors have determined inadequate reliability and low competiveness of RES (renewable energy sources).

Power supply systems with various types of installations, which use the major part of the energy potential available on a particular territory, can improve the reliability and competiveness of RES for isolated objects. The essential feature of such renewable power supply systems is the use of multiple renewable energy sources and a wide range of different types of equipment: WT (wind turbines), PC (photoelectric converters), SCP (solar collecting panels), sHEPS (small hydro-electric power station), BU (biogas units), HP (heat pumps), etc.

Current approaches to the description of integrated systems are numerous. Their analysis can be presented in a large-scale classification of different production clusters. It determines the object of the research in question – the power supply systemfor isolated power suppliers, or *technology process cluster of RES* or, simply, *RES cluster*.

It is indicated in the diagram that the technology RES cluster is formed by a group of different types of equipment (as a part of power supply system), which are different in sources of energy (sun, wind, water, geothermal heat) but common in their renewable (non-depletable) nature.

The disadvantage of renewable energy sources is their stochasticity; it leads to the risk of energy shortages or essentially reduces the reliability of energy supply.

In this regard, we face the problem of the risk measurement and its influence on power supply.

## 2. Methods and Results

### *2.1. Risks connected with the use of the renewable energy sources and RES clusters*

Risks in renewable energy are possible loss of energy supply stimulated by an advent of casual unfavorable events (zero wind or sun, low water level). In other fields of activity, risk is also understood as damage (Knight, 1921). The latter may be impersonal, i.e. be determined by an external influence. However, a risk, as a possible loss, can be frequently related with a choice of one or another solution, behavior or alternative. In this case, it is a choice of the RES equipment. It should be noted that a risk is sometimes understood as a possibility of occurrence of an unfavorable event. The higher is the possibility, the greater is the risk.

If direct measurement of losses or their possibility is impossible, risks can be measured via ranking of corresponding objects, processes or events in respect of possible losses, damages, etc. Ranking is usually based on experts' judgments.

A natural reaction to the presence of risks in the field of renewable energy is a will to use different types of energy simultaneously, diversify the RES equipment, i.e. to divide the general problem of energy production among different types of RES installations. Diversification is a conventional instrument to reduce many types of risks. An increase in the number of components (RES equipment) decreases the overall risk.

The second way to reduce the influence of risks is the risk management. Risk management is performed by various methods: for example, through accurate calculation of combinations of installed capabilities for each type of the RES equipment.

However, the risk management obtains a reliable basis and consequences of diversification become analyzable via methods of mathematical statistics only in those cases, where a risk can be measured and represented in a form of a statistical factor (Bendat, Piersol, 1971).

In mathematical analysis, the risk is frequently measured by such ordinary statistical characteristics as dispersion and root-mean square deviation. Both characteristics measure the variation from average values. The bigger are variations, the higher is the

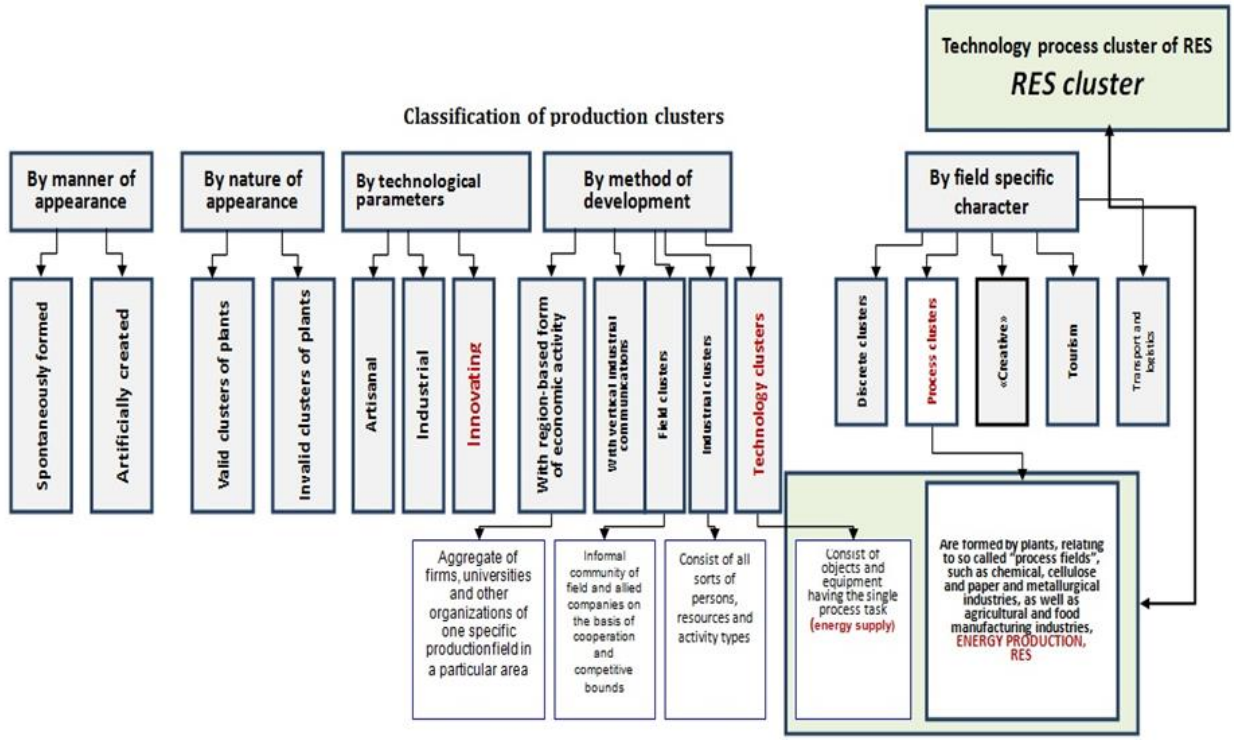


Figure. 1. The place of the power supply system based on RES, as a technology process cluster of RES, within the system of the general classification of production clusters

spread of indexes around the average and, consequently, the greater is the risk level.

The correlation between the dispersion D and the root-mean square deviation is as follows:

$$\sigma = \sqrt{D}\ .$$

Whereas the sampling variance for the average one is determined as

$$D = \sum \frac{(x_i - \bar{x})^2}{n-1},$$

where:

*n* is the quantity of observations;

*x* is the average of the stochastic variable x.

As it is known, the mean-root square deviation has an undeniable advantage: in case real distribution is in close proximity to the normal one (that should be verified statistically, of course), this parameter can be used to determine the range, wherein the value of the stochastic variable is expected to appear with the specified probability. Thus, when speaking about the distribution of production costs of 1 kW*h by a RES technology cluster, it is possible to state that the value of the stochastic variable x (in this case, it is the production cost of 1 kW*h by a RES cluster) is within the limits ~x±s with the probability of 68%; with the probability of 95%, it is within the limits x±2s and so on (Fig. 2).

*2.2. Cost of the energy produced by a RES cluster and the dispersion of 1 kW*h production cost*

Now we specify the impact of diversification on the minimization of risks and elicit conditions, in which this impact is achieved. Let us assume that the test object is some theoretical technology cluster of RES (hereinafter – *RES cluster*). This assumption is caused by methodological advantages – in this case, it is easier to understand the relationship among the basic variables. However, many obtained results can be easily extended to any RES system.

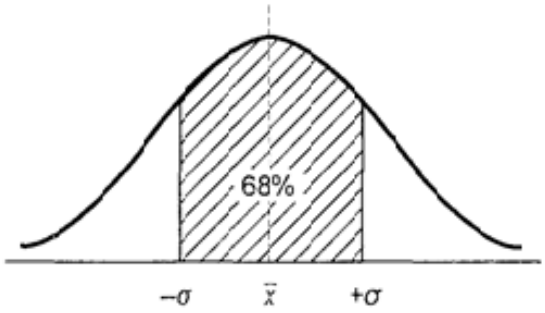


Figure 2. Distribution of the values of the stochastic variable x

The dispersion of 1 kW*h production cost can serve as an instrument to measure the risk during a long-term use of RES. The diversification of the equipment (if applied correctly) leads to a decrease of this dispersion, other conditions being equal. Diversification is based on the simple hypothesis. If each component of a RES cluster is characterized by some dispersion of 1 kW*h production cost, the total dispersion of 1 kW*h production cost is determined by its composition. Thus, changes in the composition of

the RES cluster initiate changes in the total dispersion of reliability. In some cases, the total dispersion can be reduced to a minimum (Esipov, 2008).

Let us consider a technology RES cluster consisting of *n* types of energy sources. A type of equipment in the cluster is denoted as *i*, the number of equipment types is $a_i$. The production cost of 1 kW*h for one *i* makes a *d* value. *A* is the total production cost of 1 kW*h. It is equal to:

$$A = \sum a_i d_i \quad (1)$$

If $d_i$ is the average cost of 1 kWh produced by the equipment, then *A* value characterizes the average production cost of 1 kWh produced by the RES cluster in total.

Let us assume that indexes of the production cost of 1 kWh from different energy sources are statistically independent values (in other words, they do not correlate with each other). In this case, the dispersion of 1 kWh production cost by the entire cluster (represented as D) can be figured as

$$D = \sum a^2_i D_i \quad (2)$$

Where $D_i$ is the dispersion of cost of 1 kWh produced by the equipment of the *i*-type.

For simplicity (that will by no means affect results of the further discussion), we will change over from absolute measurement of RES equipment quantity to relative measurement. Now, let $a_i$ describe a segment (or share) of an *i*-type in the RES cluster. Consequently, $0 < a_i < 1$; $\sum a_i = 1$.

For indexes of 1 kWh production cost of a RES cluster, which are dependent in a statistical sense, the dispersion of overall reliability is determined in the following way:

$$D = \sum a^2_i D_i + 2 \sum a_i a_j r_{ij} \sigma_i \sigma_j \quad (3)$$

where $D_i$ is the dispersion of 1 kWh production cost for *i*-type of equipment;

$r_{i\,j}$ is the correlation factor of the cost of 1 kWh produced by the equipment of types *i* and *j*;

$s_i$ and $s_j$ are the root-mean square deviation of the production cost of 1 kWh for the equipment of types *i* and *j*. The evidence of validity of formulas (2) and (3) are not given in this paper as they can be found in textbooks on mathematical statistics (Knight, 1921).

The correlation factor of two stochastic variables *x* and *y* is known; it is determined in accordance with the formula (4):

$$r_{xy} = \sum (x-\bar{x})(y-\bar{y}) / n \sigma_x \sigma_y \quad (4)$$

Where *x* and *y* are the average values of two RES types (in this case, the average production costs of 1 kWh).

The correlation factor is frequently calculated according to the following operating formula:

$$r_{xy} = \frac{n\sum xy - \sum x \sum y}{\sqrt{[\sum x^2 - (\sum x)^2][n\sum y^2 - (\sum y)^2]}}.$$

This factor can be a positive or a negative value. With positive correlation, the dispersion of energy production cost of 1 kW*h increases; with negative correlation it decreases. As a matter of fact, with a significant negative correlation, positive deviations from the average production cost of 1 kW*h generated by a RES system are liquidated by the negative deviations of others. Conversely, with positive correlation, the deviations are summarized, which increases the total dispersion and risk.

Specialists are well aware of the following characteristics of correlation factor:

- factor has no dimension; consequently, it is comparable to different data series;
- $r_{xy}$ value lies within the range from -1 up to +1. The value $r = +1$ is a reflection of the existence of full positive correlation between the variables, i. e. there is a functional linear dependence – with increase of x, y increases in a linear manner. When r = -1, the negative linear dependence is observed.

Let us now understand the effect of the size of RES equipment diversification on the risk value. The size of diversification is a number of objects possible for use in one technology cluster of RES. Let us refer to an illustrative example, which will allow us to highlight the influence of the factor mentioned above. Let a RES cluster consists of different types of equipment having the same dispersion of the production cost of 1 kW*h $s^2_0$. The specific weights of each type of equipment (PC, WT, etc.) are also similar and the total sum of equipment shares (in terms of installed capacity) is equal to 1. Assuming that indexes of the production cost of 1 kWh in individual types of RES equipment are independent, we can use the formula (2). Within this framework, in order to estimate the amount of root-mean square deviation of 1 kWh production cost, we get:

$$D = \frac{1}{n}\sigma_0^2,$$

Where *n* is the number of types of RES equipment.

Using the formula mentioned above, we will determine a dispersion of 1 kW*h production cost produced by a RES technology cluster consisting of two or three RES types. For two different sources, we have:

$$D = \frac{1}{2}\sigma_0^2 \quad \text{and} \quad \sigma = \sqrt{\frac{1}{2}} \times \sigma_0 = 0{,}71\,\sigma_0.$$

For three types of RES equipment, the square deviation of 1 kW*h production cost is $0.58s_0$. Thus, with an increase in the number of RES cluster equipment, risk decreases, even if the dispersion of constituent elements is the same. However, diversification effectiveness decreases, i.e. the cost of the installed equipment grows. The corresponding dependence is shown in Fig. 3.

Diversification scaling-up has the biggest influence at initial stages – when *n* values are small. For example, in the considered example, a transition from one RES type to four decreases the square deviation by 50%, and from one to eight – by 65%.

The above findings, concerning the tendency of root-mean square deviation change depending on the

number of elements, when the dispersions of the elements are equal, are valid for other, more general, cases. However, the dependency of this parameter on the degree of diversification is not so clear then.

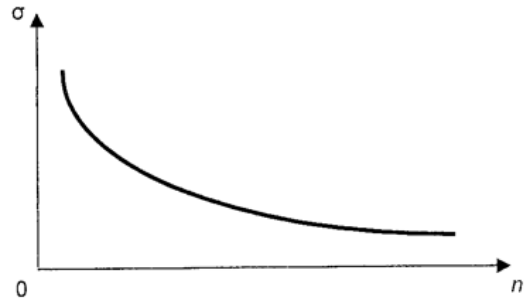


Figure 3. Diagram of diversification influence (growth of different RES types equipment) on risk.

Now let us see the changes in the cost and risk value in a case when the technology cluster of RES is restructured. To do this, formulas (2) and (3) should be written for two RES types: X (WT) and Y (PC). This analysis is of practical importance as these types are most available and understandable for consumers. It helps to illustrate the consequences of *mixing* RES equipment with different production costs of 1 kW*h of energy and different dispersion. For the independent sources:

$$D = a^2_x D_x + a^2_y D_y \quad (5)$$

and for dependent parts of equipment in composition of RES cluster, it is:

$$D = a^2_x \sigma^2_x + a^2_y \sigma^2_y + 2a_x a_y r_{xy} \sigma_x \sigma_y \quad (6)$$

Where $a_y = 1 - a_x$.

In this case, the average value of 1 kW*h production cost is defined as:

$$A = a_x d_x + (1 - a_x) d_y \quad (7)$$

If $d_y > d_x$. and $s_y > s_x$, then an increase in the share of the most effective type of RES will decrease the 1 kW*h energy production cost. Thus, based on (7), we will obtain:

$$A = d_x + (d_y - d_x) a_x \quad (8)$$

As for the dispersion, it follows from the expression (6) that the proposition is ambiguous and depends on the sign and the degree of correlation. In this regard, let us have a closer look at three situations:

- complete positive correlation of 1 kWh production cost between types of the RES equipment ($r_{xy} = +1$),
- complete negative correlation ($r_{xy} = -1$), independence of 1 kWh production cost between types of the RES equipment,
- zero correlation ($r_{xy} = 0$).

In the first case, the increase of production cost of 1 kWh between two types of the RES equipment, due to the integration of Y in addition to existing X, is followed by the increase of both production cost and the dispersion. For a technology cluster of RES with two types of the equipment, the square deviation is within the limits $s_x < s < s_y$ (Fig. 4).

For a special case, when $s_x = s_y = s$, we will obtain $D = s^2$ – by the formula (6). In other words, *mixing* equipment types in a RES cluster will have no influence on the dispersion value here.

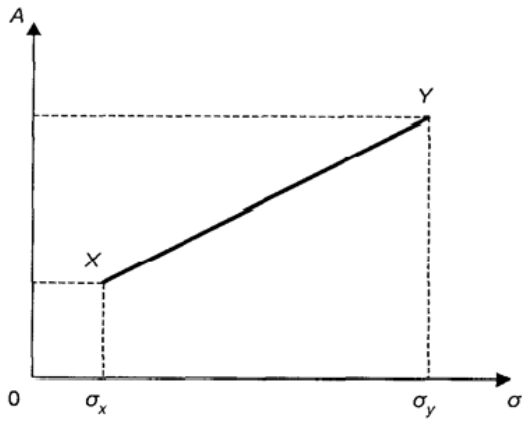


Figure 4. Diagram of values of square deviation for a technology cluster of RES with X and Y types of equipment.

A weak point of the situation with additional components to a RES cluster is a considerable increase of its cost. Therefore, it requires use of methods of the mathematical optimization and their classification in terms of the equipment structure and the installed capacity of the RES cluster.

In a general case, for mathematical analysis, the RES cluster can be presented as a function diagram (see Fig.5). Consideration of the object in the way shown in Fig. 5 is built up on the principle of a *black box*, as a base in performing the optimization task (Esipov et al., 2008).

It was correctly supposed that the perturbation influences $W_i$ cannot be controlled. They are either stochastic or vary in time (wind speed, insolation, temperature). They determine the stochasticity of the mathematical model.

Finding solutions for such a task with the help of a *black box* is carried out through mathematic simulation, using the method of convex optimization (Sharpe, 1963).

The target function for the mathematical model of the RES cluster is a quadratic function from $x_1, x_2, \ldots, x_n$, of the following type:

$$D(Y/a) = \sum_{i=1}^{n}\sum_{j=1}^{n} \sigma_{ij} x_i x_j \Rightarrow \min, \quad (9)$$

Where $x_i$ is quantities of the installed capacity of each type of renewable energy sources of the RES cluster;

$Y / a$ is the energy cost produced by the cluster per unit time;

$\sigma_{ij}$ is the sample covariance calculated on sampling for $Y_i, Y_j$.

The physical meaning of the function is minimization of dispersion for the cost of energy produced by the power supply system (RES cluster) per unit time**.** The problem involves a choice of $x_k$ with a *minimum risk* and minimum production cost of 1 kW*h under the following restrictions:

$$x_0 + x_1 + x_2 + \ldots + x_n = 1; \quad x_0 r_0 + x_1 m_1 + \ldots + x_n m_n = A;$$

$A<r_0$ ; $x_i \geq 0, \quad i = 0,1,...,n$

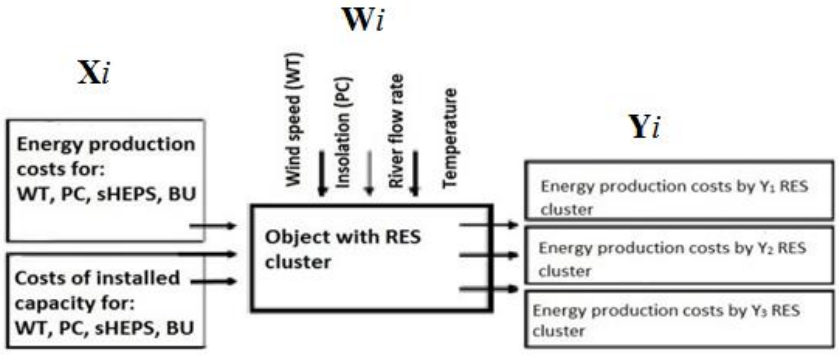


Figure 5. Algorithm of a multifactorial discrete mathematical model of a RES cluster

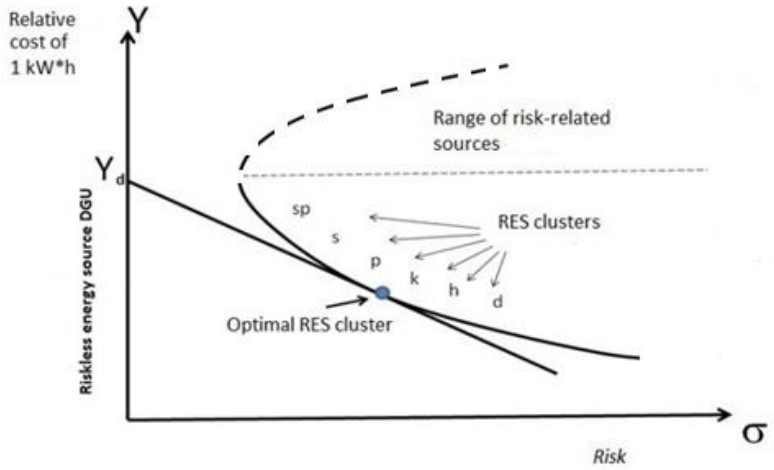


Figure 6. Diagram to define the optimal RES cluster and evaluate the risk of energy supply (%)

It is a convex programming problem, which is solved using the Sover Add-in in Excel. As a result, we will receive a vector ($x_0$, $x_1$, ..., $x_n$) that defines the effectiveness of the RES cluster depending on the equipment structure. With regard to the RES cluster, it is nothing but finding an optimum relation of fraction capacity of $x_{DGU}$, $x_{WT}$, $x_{PC}$, ...$x_n$ (DGU is a diesel generator unit).

The visualization algorithm of finding the effective RES cluster is shown in Fig. 6 (Tobin, 1965).

The value evaluates risks, i.e. it is a variation of cost of energy produced by the cluster per unit time. Such an approach is known in investment analysis, where the corresponding model includes risk-related and risk-free financial instruments; it is called *Tobin's portfolio approach* (Tobin, 1965).

The area of the variety of risk values and possible clusters is called the *Markowitz bullet*, as its form resembles a bullet and was described by the Nobel laureate Markowitz in his works on creation of optimal investment portfolio on the base of risk-related valuable securities (in renewable energy, we would say *stochastic* sources) (Markowitz, 1952, 1990).

A single renewable energy installation usually tends to be oversized to accommodate load demand. Combinations with one or more sources of the renewable energy will improve load factors and help to maintain and replace cost as well (Fulzele, Dutt, 2012). Their development is dependent on the improvement of processing, decrease in the cost price of the produced useful energy and increase in the operation comfort. On the side of the resources, the potential of renewable energies could noticeably exceed the needs, but their contribution to the energy balance depends on available surfaces, investments for their equipment and the reduction of consumption (Lakhoua, 2014).

## 3. Conclusions

1. The use of power delivery systems built on the principles of diversification (variety of sources) of RES technology clusters increases the reliability of energy supply of stand-aloneobjects.
2. Risk management (decrease of probability of object's power failure) is subject to the selection of the optimal equipment structure of RES based on different principles for obtaining the renewable energy.
3. Research of solutions on finding the most effective equipment structure of an

integrated energy system – RES cluster – can be carried out on the base of mathematic simulation, using the method of convex optimization.

4. Scietific literature includes several studies dedicated to energy production cost analysis of renewable energy sources. Compared to them, this study has shown the specific diversified minimization of risks and elicited their conditions; it is quite different in logic and methodological advantages. It has also described a unique process algorithm of a multifactorial discrete mathematical model of a RES cluster.

## References


1. KNIGHT F., 1921, *Risk, Uncertainty and Profit*, Houghton Mifflin, Boston and New York.
2. BENDAT J., PIERSOL A., 1971, *Random data: Analysis and measurement processes*, Wiley Interscience, New York.
3. ESIPOV Y.V., SAMSONOV F.A., CHEREMISIN A.I., 2008, *Monitoring and evaluation of system risks*, Publishing house LKI, Moscow.
4. SHARPE W.F., 1963, A Simplified Model for Portfolio Analysis, in: *Management Science*, vol. 9(2), p. 277-293.
5. VELKIN V., 2013, The use of the graphical model for the RES cluster for determining the optimal composition of the equipment of renewable energy sources, in: *World Applied Sciences Journal*, vol. 29(9), p. 1343-1348.
6. TOBIN J., 1965, The Theory of Portfolio Selection, in: *The Theory of Interest Rate*, eds. Hahn F.N., Brechling F.R.P., Macmillan, London.
7. MARKOWITZ H.M., 1952, Portfolio selection, in: *Journal of Finance*, vol. 7(1), p. 77-91.
8. MARKOWITZ H.M., 1990, *Mean-Variance Analysis in Portfolio Choice and Capital Markets*, Blackwell, Cambridge, MA.
9. FULZELE J.B., DUTT S., 2012, Optimium Planning of Hybrid Renewable Energy System Using HOMER, in: *International Journal of Electrical and Computer Engineering*, vol. 2(1), p. 68-74.
10. LAKHOUA M.N., 2014, System Analysis of a Hybrid Renewable Energy System, in: *International Journal of Electrical and Computer Engineering*, vol. 4(3), p. 343-350.

**PROBLEMY EKOROZWOJU – PROBLEMS OF SUSTAINABLE DEVELOPMENT**
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# Issues of Sustainable Development in the Light of a GIS-based Assessment of the Geochemical State of the Aquatic Environment

# Problematyka zrównoważonego rozwoju w świetle oceny geochemicznego stanu środowiska wodnego przy wykorzystaniu systemu GIS

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## Abstract

This paper investigated issues around sustainable development in light of the assessment of the geochemical state of an aquatic environment, focussing on the accumulation of contaminants in sediments. The analysis was carried out on the concentrations of nine metals: As, Ba, Cd, Co, Cr, Cu, Ni, Pb, and Zn. Classification of results was based on geochemical criteria. The results relate to the background geochemical values characterised by natural conditions without human interference. Using GIS, maps were compiled which highlighted the spatial distribution of the contaminants, namely for the selected heavy metals (Ba, Cr, Cu, Ni, Pb and Zn). These maps enabled the relationships between these elements to be studied. Analysis of sediments contaminated by heavy metals is an important tool in environmental monitoring.

The study showed that potential contamination in sediments can reach significant levels. Therefore, systematic monitoring of metal concentrations in the sediment should encompass the greatest number of reservoirs possible. This will enable ecological equilibrium to be maintained in aquatic environments. This will help to identify, eliminate, and prevent the negative effects of human economic activities which will improve the rational utilisation of environmental resources, important from the sustainable development point of view.

**Key words:** sustainable development, State Environmental Monitoring, sediments, heavy metals, Geographic Information System, GIS

## Streszczenie

W pracy podjęto problematykę zrównoważonego rozwoju w świetle oceny geochemicznego stanu środowiska wodnego, koncentrując się na zanieczyszczeniach kumulujących się w osadach dennych. Analizę przeprowadzono w kontekście zawartości dziewięciu metali (As, Ba, Cd, Co, Cr, Cu, Ni, Pb i Zn). Klasyfikację pozyskanych wyników badań przeprowadzono na podstawie kryteriów geochemicznych. Rezultaty analiz odniesiono do wartości tła geochemicznego charakteryzującego warunki naturalne bez piętna antropopresji. Wykorzystując system GIS opracowano mapy przestrzennego rozkładu zanieczyszczeń wybranymi metalami ciężkimi (Ba, Cr, Cu, Ni, Pb i Zn), które pozwoliły na zaobserwowanie zależności pomiędzy badanymi elementami. Analiza zanieczyszczeń osadów dennych metalami ciężkimi jest istotnym narzędziem do monitoringu środowiska.

Przedstawione badania wykazały, że potencjalny poziom zanieczyszczeń w osadach dennych może osiągnąć znaczący poziom. Systematyczną kontrolą zawartości metali w osadach warto objąć jak największą ilość zbiorników wodnych. Umożliwi to zachowanie równowagi ekologicznej w ekosystemie środowisk wodnych. Działanie to pomoże w identyfikacji, likwidacji i zapobieganiu negatywnych skutków działalności gospodarczej człowieka, co poprawi istotne z punktu widzenia rozwoju zrównoważonego racjonalne użytkowanie zasobów środowiska naturalnego.

**Słowa kluczowe:** zrównoważony rozwój, PMŚ, osady denne, metale ciężkie, GIS

## Introduction

The current commonly used definition of sustainable development was introduced in the 1987 report *Our Common Future* by the United Nations World Commission on Environment and Development. It was defined as *development that meets the needs of current generations without compromising the ability of future generations to meet their own needs* (WCED, 1987). Sustainable development is considered on three levels: economic, social and environmental. The interactions between these aspects should be harmonious and non-invasive in relation to the remaining spheres (Miksch, 2015). Unfortunately, civilisation's dynamic progress, based on continuous growth in the consumption of goods and services, fossil fuels, the development of the automotive industry, mass production of single-use products, and accumulation of waste is often done without respecting the values and resources of the natural environment (Pawłowski, 2009; Sobczyk et al., 2012). As a result of these activities many pollutants are produced. Among them, heavy metals play a specific role, not only because of their potential toxicity, but also because once they enter into the environment they are practically impossible to remove. They remain in the natural environment circulating between its various components. This has a particularly important significance in relation to aquatic ecosystems. Rising heavy metal concentrations in oceans and seas could undermine the proper functioning of trophic chains. An example might be the inhibition of plankton growth which may result in a reduction in fish populations. Pollution associated with coal combustion, such as mercury emissions, also applies to water. In the United States, approximately 50,000 lakes, streams and ponds contain water unfit for human consumption due to their high mercury content (Berdo, 2006; Pawłowski, 2011). Elevated concentrations of heavy metals in the natural environment can cause serious health consequences, not only for current generations, but also for future ones.

This paper highlights the risks associated with the accumulation of contaminants in sediments. They provide sensitive pollution monitoring indicators (Vandecasteel, 2004). The majority of potentially harmful metals and organic compounds are retained in sediments which find their way to the surface waters. They accumulate elements that were or are currently widely used in the economy e.g. Zn, Cu, Cr, Ca, Pb, Ni, and Hg (Ekoinfonet, 2016). Knowledge of heavy metal content in sediments could be used to precisely determine the chemical characteristics of the aquatic environment and the geochemical state prevailing in the catchment area, as well as to define the spread of pollution and to identify its sources. This is primarily important for small water reservoirs, which are usually unmonitored and not included in environmental reports (Gałka, Wiatkowski, 2010).

The study made use of a Geographic Information System (GIS), which is becoming one of the most important tools in the geochemical assessment of the environment. This system allows efficient analyses to be conducted on large volumes of data with subsequent visualisation of the results. GIS also allows results to be classified and predicted on the basis of additional information (Zhang, Selinus, 1998).

## Purpose

The purpose of the study presented in this paper was to demonstrate the principle in the use of GIS in meeting the requirements of sustainable development through environmental monitoring. In particular, GIS may be useful when planning activities whose purpose is to protect the natural environment, thus allowing future generations to exist appropriately.

To achieve this goal it was decided to assess contamination levels in the reservoir's sediment for the following selected heavy metals: As, Ba, Cd, Co, Cr, Cu, Ni, Pb, and Zn. Sediments were classified using geochemical criteria and maps were compiled based on the distribution of heavy metal contamination. At the same time the cause of the accumulation of individual heavy metals in the reservoir was to be determined as this contamination was inconsistent with the principles of environmental policy.

## Study area and methodology

Due to the pilot nature of the study, one randomly selected object was chosen – the Ostrowy Reservoir approximately 25 km north of Częstochowa in Poland. The reservoir was built in the years 2000-2003 by damming the River Biała Oksza (White Oksza). The reservoir's surface area covers 39 ha.

Field work collecting sediment samples was carried out in July 2016. The sampling point locations are presented in the figures below. To develop a grid arrangement of sampling points the ArcGIS application, as well as the Web Map Service (WMS), accessed through the Geoportal service, were used (Rozpondek, Wancisiewicz, 2016). GIS was used to locate the selected sampling points.

Sediment samples were collected by lowering a Van Veen Grab supplied by KC Denmark A/S of Denmark. This is a grab sampler with an automatic latch lock which unlocks upon hitting the bottom (Geomor, 2016). 31 out of the 32 selected sampling points, from depths varying between 0.3-5.3 m were obtained from the Ostrowy Reservoir. A sample from sampling point 31 was not obtained due to its inaccessibility.

In the laboratory the samples were firstly dried under dry-air conditions and then sieved through a 2mm screen. They were then dried in an oven at 105°C to constant weight and ground in a vibrating mill until the grain size was less than 0.2 mm. A sample so

Table 1. Heavy metal concentrations and geochemical class in the reservoir's sediment

| Sampling Point | pH $H_2O$ | As | Ba | Cd | Co | Cr | Cu | Ni | Pb | Zn |
|---|---|---|---|---|---|---|---|---|---|---|
| | | [ppm] | | | | | | | | |
| 1 | 7.16 | 0.8 class 1 | 91.3 class 1 | 0.0 class 1 | 0.0 class 1 | 20.9 class 2 | 16.2 class 1 | 13.4 class 1 | 20.9 class 1 | 142.5 class 1 |
| 2 | 7.29 | 0.0 class 1 | 28.5 class 1 | 0.0 class 1 | 0.0 class 1 | 182.3 class 3 | 2.8 class 1 | 77.1 class 3 | 1.8 class 1 | 11.8 class 1 |
| 3 | 7.11 | 0.9 class 1 | 129.4 class 1 | 0.0 class 1 | 0.0 class 1 | 10.4 class 1 | 12.4 class 1 | 8.9 class 1 | 18.4 class 1 | 106.0 class 1 |
| 4 | 7.02 | 1.0 class 1 | 134.1 class 1 | 0.0 class 1 | 0.0 class 1 | 11.0 class 1 | 13.6 class 1 | 7.9 class 1 | 17.6 class 1 | 114.8 class 1 |
| 5 | 7.48 | 0.0 class 1 | 18.3 class 1 | 0.0 class 1 | 0.0 class 1 | 190.7 class 3 | 2.5 class 1 | 81.2 class 3 | 0.0 class 1 | 10.1 class 1 |
| 6 | 7.25 | 0.0 class 1 | 26.3 class 1 | 0.0 class 1 | 0.0 class 1 | 157.9 class 3 | 2.2 class 1 | 65.8 class 3 | 2.8 class 1 | 12.8 class 1 |
| 7 | 7.16 | 0.9 class 1 | 102.7 class 1 | 0.0 class 1 | 0.4 class 1 | 44.6 class 2 | 12.2 class 1 | 23.0 class 1 | 21.9 class 1 | 100.6 class 1 |
| 8 | 7.36 | 0.0 class 1 | 32.7 class 1 | 0.0 class 1 | 0.0 class 1 | 168.3 class 3 | 3.6 class 1 | 71.4 class 3 | 6.9 class 1 | 26.6 class 1 |
| 9 | 7.29 | 0.0 class 1 | 42. class 1 | 0.0 class 1 | 0.0 class 1 | 80.4 class 2 | 4.0 class 1 | 38.2 class 2 | 20.2 class 1 | 45.7 class 1 |
| 10 | 7.18 | 2.7 class 1 | 138.0 class 1 | 0.0 class 1 | 0.6 class 1 | 16.9 class 1 | 17.4 class 1 | 11.4 class 1 | 29.0 class 1 | 160.5 class 1 |
| 11 | 7.56 | 0.0 class 1 | 21.6 class 1 | 0.0 class 1 | 0.4 class 1 | 303.5 class 3 | 2.1 class 1 | 128.0 class 1V | 1.8 class 1 | 8.9 class 1 |
| 12 | 7.49 | 0.0 class 1 | 19.9 class 1 | 0.0 class 1 | 0.0 class 1 | 101.2 class 3 | 1.6 class 1 | 41.7 class 2 | 0.0 class 1 | 7.1 class 1 |
| 13 | 7.12 | 0.0 class 1 | 49.3 class 1 | 0.0 class 1 | 0.6 class 1 | 188.1 class 3 | 5.4 class 1 | 80.3 class 3 | 22.9 class 1 | 40.7 class 1 |
| 14 | 7.43 | 0.0 class 1 | 30.2 class 1 | 0.0 class 1 | 0.3 class 1 | 244.0 class 3 | 2.7 class 1 | 103.6 class 1V | 6.4 class 1 | 19.4 class 1 |
| 15 | 7.30 | 0.0 class 1 | 42.5 class 1 | 0.0 class 1 | 0.0 class 1 | 180.4 class 3 | 3.6 class 1 | 78.2 class 3 | 5.6 class 1 | 43.3 class 1 |
| 16 | 7.25 | 0.0 class 1 | 26.6 class 1 | 0.0 class 1 | 0.0 class 1 | 133.3 class 3 | 2.5 class 1 | 56.6 class 3 | 4.5 class 1 | 64.0 class 1 |
| 17 | 7.35 | 0.0 class 1 | 34.8 class 1 | 0.0 class 1 | 0.0 class 1 | 76.4 class 2 | 1.6 class 1 | 32.2 class 2 | 3.5 class 1 | 18.7 class 1 |
| 18 | 7.51 | 0.0 class 1 | 18.7 class 1 | 0.0 class 1 | 0.0 class 1 | 28.8 class 2 | 0.8 class 1 | 12.9 class 1 | 0.0 class 1 | 8.9 class 1 |
| 19 | 7.74 | 0.0 class 1 | 22.7 class 1 | 0.0 class 1 | 0.0 class 1 | 66.5 class 2 | 2.2 class 1 | 30.0 class 2 | 1.5 class 1 | 7.0 class 1 |
| 20 | 7.27 | 2.3 class 1 | 115.7 class 1 | 0.0 class 1 | 1.2 class 1 | 33.4 class 2 | 17.9 class 1 | 18.8 class 1 | 30.7 class 1 | 189.7 class 1 |
| 21 | 7.18 | 1.5 class 1 | 171.0 class 2 | 0.0 class 1 | 1.6 class 1 | 23.9 class 2 | 19.1 class 1 | 13.9 class 1 | 35.3 class 1 | 225.8 class 2 |
| 22 | 7.26 | 1.9 class 1 | 133.8 class 1 | 0.0 class 1 | 1.4 class 1 | 26.6 class 2 | 18.4 class 1 | 15.9 class 1 | 31.7 class 1 | 232.8 class 2 |
| 23 | 7.30 | 0.0 class 1 | 48.6 class 1 | 0.0 class 1 | 0.0 class 1 | 114.6 class 3 | 4.6 class 1 | 48.7 class 2 | 6.8 class 1 | 46.8 class 1 |
| 24 | 7.41 | 0.0 class 1 | 37.6 class 1 | 0.0 class 1 | 0.0 class 1 | 141.9 class 3 | 2.4 class 1 | 61.0 class 3 | 4.4 class 1 | 31.6 class 1 |
| 25 | 7.20 | 5.8 class 1 | 264.1 class 2 | 1.0 class 2 | 5.7 class 1 | 50.3 class 2 | 28.5 class 2 | 26.8 class 1 | 57.7 class 2 | 355.5 class 2 |
| 26 | 7.11 | 6.4 class 1 | 208.8 class 2 | 1.0 class 2 | 5.7 class 1 | 39.8 class 2 | 31.9 class 2 | 29.6 class 1 | 52.1 class 2 | 441.6 class 2 |
| 27 | 6.86 | 0.4 class 1 | 43.4 class 1 | 0.0 class 1 | 0.0 class 1 | 42.5 class 2 | 3.3 class 1 | 19.6 class 1 | 9.2 class 1 | 52.0 class 1 |
| 28 | 7.04 | 0.7 class 1 | 70.6 class 1 | 0.0 class 1 | 0.0 class 1 | 47.5 class 2 | 5.1 class 1 | 23.0 class 1 | 14.2 class 1 | 72.2 class 1 |
| 29 | 6.49 | 0.0 class 1 | 106.0 class 1 | 0.0 class 1 | 0.0 class 1 | 52.8 class 2 | 13.0 class 1 | 20.1 class 1 | 12.6 class 1 | 70.7 class 1 |
| 30 | 6.91 | 0.0 class 1 | 25.4 class 1 | 0.0 class 1 | 0.0 class 1 | 65.2 class 2 | 1.3 class 1 | 25.5 class 1 | 3.8 class 1 | 22.8 class 1 |
| 32 | 7.21 | 4.8 class 1 | 225.7 class 2 | 0.5 class 1 | 6.3 class 1 | 56.2 class 2 | 25.8 class 2 | 31.0 class 2 | 49.8 class 1 | 317.7 class 2 |

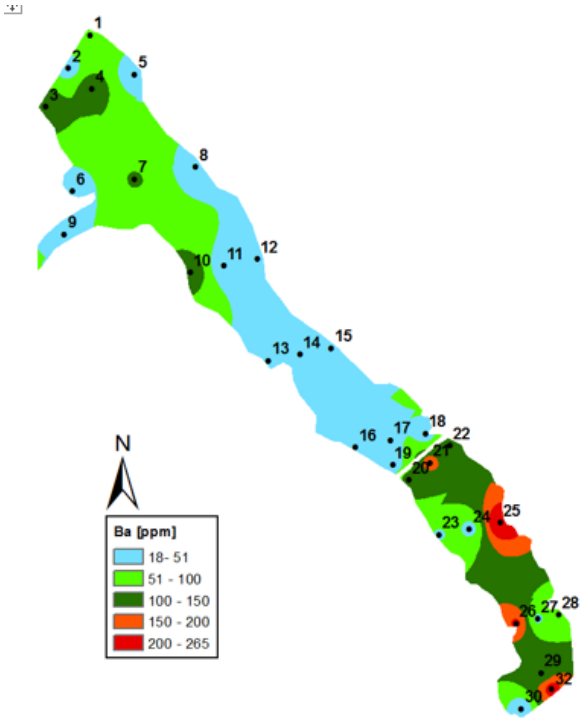


Figure 1. Spatial distribution of Ba concentrations [ppm]

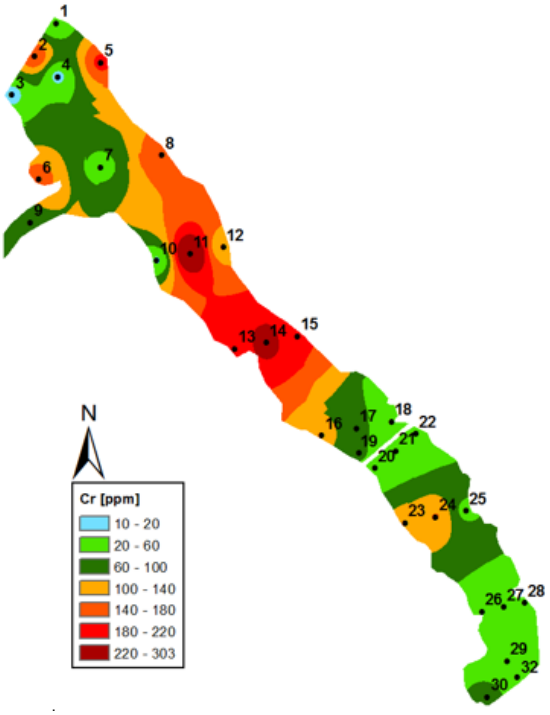


Figure 2. Spatial distribution of Cr concentrations [ppm]

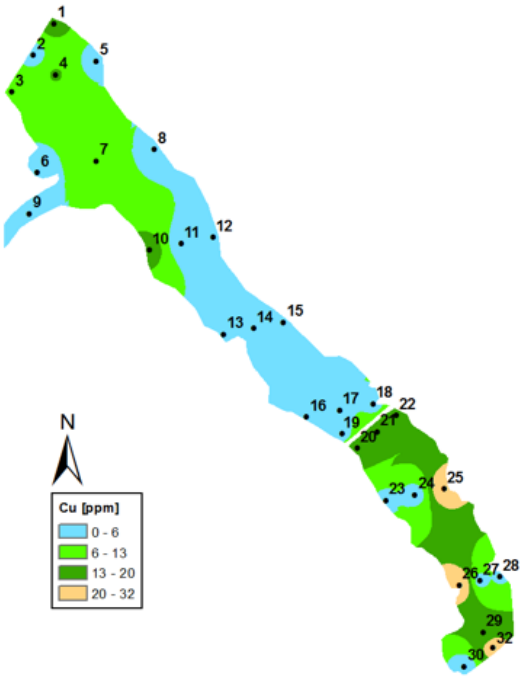


Figure 3. Spatial distribution of Cu concentrations [ppm]

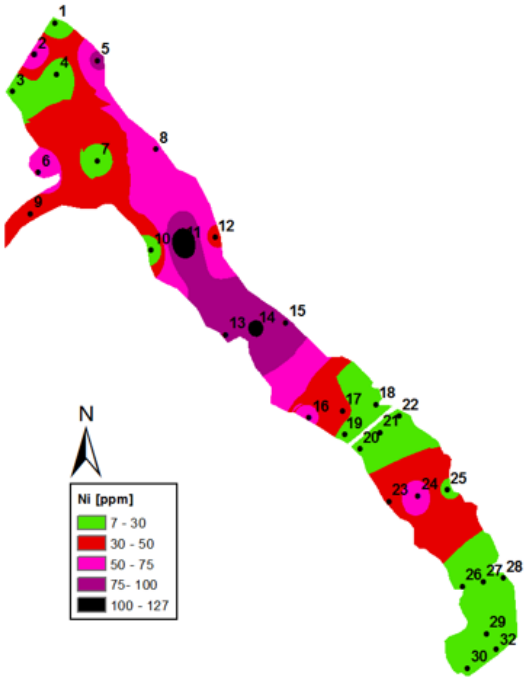


Figure 4. Spatial distribution of Ni concentrations [ppm]

prepared was used to determine the total heavy metal content. *Aqua regia* (a mixture of concentrated hydrochloric acid and nitric acid in a volumetric ratio of 3:1) was used for metal extraction. Mineralisation was carried out at 180°C, for 30 minutes in a high pressure microwave mineraliser from the German company Berghof GMBH. Three samples were prepared from each sediment sample for analysis. A plasma spectrometer (IRIS ICP-OES Thermo) determined the heavy metal content. The pH value was also recorded using a volume fraction sediment suspension in water in accordance with the PN-ISO 10390:1997 standard (Rozpondek, Wancisiewicz, 2016).

Sediment contamination was evaluated using maximum heavy metal concentration values in the classification of aquatic sediment quality as defined by the Polish Geological Institute (Bojakowska, Sokołowska, 1998; Bojakowska, 2001).

GIS was used to identify the location for the results of each sample point within the ArcMap application the ArcGIS Esri program was used to make inverse-

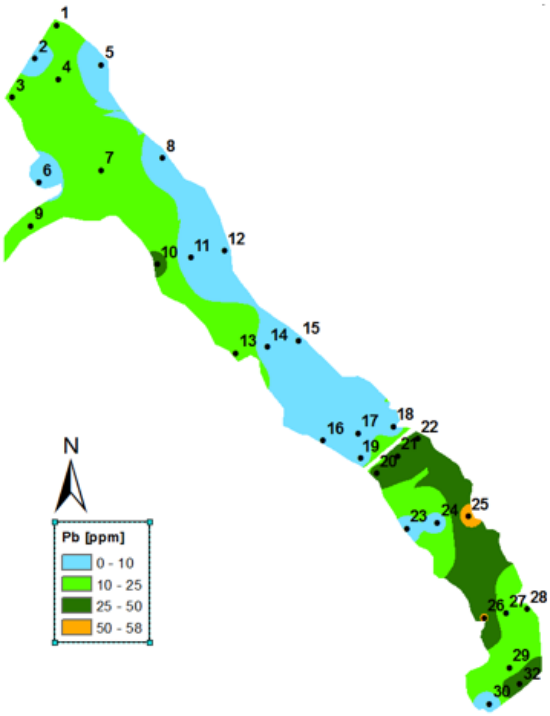


Figure 5. Spatial distribution of Pb concentrations [ppm]

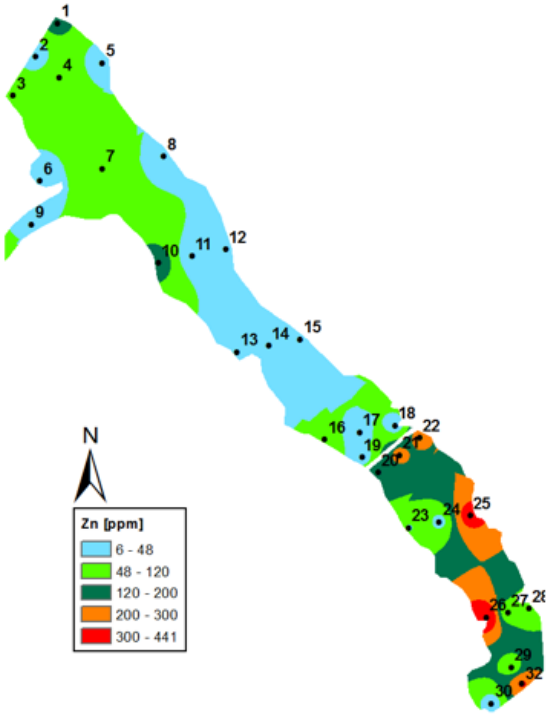


Figure 6. Spatial distribution of Zn concentrations [ppm]

distance weighting interpolations (Tomczak, 1998) for the laboratory analysis of the collected sediment samples. Afterwards, for visualisation purposes, classes were generated for the heavy metal concentrations in accordance with the geochemical criteria for aquatic sediments.

## Results and discussion

Table 1 shows the results for the total concentrations of heavy metals in the sediment of the Ostrowy Reservoir, together with the classification of the aquatic sediments based on geochemical criteria (Bojakowska, Sokołowska, 1998; Bojakowska, 2001). Attention was also paid to the natural background geochemical value of the heavy metal in the environment, which is related to its geological substrate. Maps were compiled showing the differences in contamination levels for the various heavy metals (Figs. 1-6).

The reservoir's pH values were in the range 6.49-7.74 (acidic).

The samples can be considered to be uncontaminated by As, as the majority of the results for this element had a zero concentration value while the remainder were classified as Purity Class 1. The geochemical background value (<5 ppm) was exceeded only in sample points 25 (5.8 ppm) and 26 (6.4).

The Ba content exceeded the geochemical background value (<51 ppm) in 11 sampling points. The highest concentrations for this element in the sediment were noted in sampling points: 21 (171.0ppm), 25 (264.1), 26 (208.8), and 32 (225.7) which can be considered to be moderately contaminated i.e. Purity Class 2.

The Cd content in the analysed sediments was equal to zero. The exceptions were sampling points: 32 (0.5 ppm, Purity Class 1), 25 (1.0, Class 2), and 26 (1.0, Class 2).

The Co content was in the range 0.0-6.3 ppm (Purity Class 1), which means the sediment is uncontaminated. The highest cobalt concentration was recorded at sampling point 32 (6.3 ppm) which is more than three times the geochemical background value (2 ppm).

The natural Cu content (6 ppm) was exceeded at 12 sampling points. The highest concentrations were recorded at sampling points: 25 (28.5 ppm), 26 (31.9), and 32 (25.8), which can be considered to be moderately contaminated i.e. Purity Class 2

For Pb, its content in the sediment can be considered as moderately contaminating i.e. Purity Class 2. The highest recorded concentrations were at sampling points: 25 (57.7 ppm), and 26 (52.1), which exceed more than five times the geochemical background value (10 ppm).

The background geochemical Zn content in aquatic sediments is 48 ppm (as stated by Bojakowska and Sokołowska). All the tested sediment samples, with the exception of sampling points 32 (49.8 ppm, Purity Class 2), 25 (57.7, Class 2), and 26 (52.1, Class 2), did not exceed the natural zinc content in the sediments

On the basis of Figures: 1, 2, 4, and 6, it can be affirmed that the greatest concentrations of Ba, Cu, Pb, and Zn can be found in the southern part of the reservoir.

The reservoir's sediment can be regarded as being contaminated with Cr. Its concentration was in the range 10.4-303.5 ppm and therefore the sediments were classified as Class 3. The geochemical background value (5 ppm) was exceeded at all sampling points.

Ni concentrations in the sediments were classified as heavily contaminated (Purity Class 4). The highest recorded concentrations were at sampling points: 11 (128 ppm), and 14 (103.6) i.e. approximately 24 and 21 times higher than the geochemical background value (5 ppm).

On the basis of Figures 4 and 6 it can be seen that the distributions of Cr and Ni in the sediments are very similar. The highest concentrations of these elements are in the north-eastern and central parts of the reservoir.

Concentrations of the analysed elements (As, Ba, Cd, Co, Cr, Cu, Ni, Pb, and Zn) in the reservoir's sediments in the majority of cases clearly exceeded the averaged geochemical background value. This may indicate that the studied area is under the influence of harmful anthropogenic activities. Most likely, its state is linked to inadequately treated sewage from areas with open sewers created as a result of human activities related to making a living and to the economy. Another potential factor in the increased pollutants is the municipal sewerage treatment works located nearby. In addition, the increased heavy metal content in the reservoir could also be the surface runoff which introduces pollution from agricultural areas (fertilizers, pesticides) as well as sewage sludge used to fertilise farmland. This unsatisfactory geochemical situation in the reservoir may be caused by mechanisation, or more specifically, the use of fuels to drive agricultural machinery (Hazik et al., 2013; Polechoński, 2003; Kazimierowicz, Kazimierowicz, 2014; Karwacka et al., 2015) in agricultural production.

## Summary and conclusions

The following conclusions can be drawn from the study results:

1. In the analysed reservoir, sediments are characterised by highly variable concentrations of the following metals: As, Ba, Cd, Co, Cr, Cu, Ni, Pb, and Zn. The most common contaminants are Cr and Ni. The lowest contaminant concentrations in the sediment were for As, Ba, and Co.
2. GIS is an important tool as an aid in monitoring sediments in reservoirs. It enables the state of the aquatic environment to be identified, and to track and forecast changes.
3. On the basis of spatial maps showing the distribution of individual heavy metal concentrations, the relationship between Cr and Ni was noted. The highest concentrations of these heavy metals occur where the reservoir is at its deepest (north-eastern and central parts). The highest concentrations of Ba, Cu, Pb and Zn occur in the southern part of the reservoir. This implies that the contaminants are introduced into the river by the inhabitants in the surrounding villages.
4. The reservoir's sediments require further study within the environmental monitoring framework.
5. Sustainable development activities for the harmonious interaction of the social, economic and environmental spheres should be controlled at the local level, in order to prevent global natural environmental problems.
6. It is important to identify the geochemical state of small reservoirs which are usually ignored and not accounted for in environmental reports, but whose sediments may be significantly contaminated. These studies allow harmful human activities to be identified and to define directions for their prevention.
7. The pilot study shows that potential contamination concentrations in sediments can reach a significant level. Further studies are therefore required to cover more reservoirs. An internationally coordinated program of such activities would be very valuable not only on a national level of individual countries, but also throughout the whole European Union.

## References

1. BERDO J., 2006, Zrównoważony rozwój w stronę życia w harmonii z przyrodą (Sustainable development towards living in harmony with nature), in: *Earth Conservation*, p. 10-11.
2. BOJAKOWSKA I., SOKOŁOWSKA G., 1998, Geochemiczne klasy czystości osadów wodnych (Geochemical purity classes for aquatic sediments), in: *Przegląd Geologiczny*, 46(1), p. 49-54.
3. BOJAKOWSKA I., 2001, Kryteria oceny zanieczyszczenia osadów wodnych (Criteria for the assessment of contaminants in aquatic sediments), in: *Przegląd Geologiczny* 49(3), p. 213-218.
4. EKOINFONET, 2016, http://ekoinfonet.gios.gov.pl/ (28.10.2016).
5. GAŁKA B., WIATKOWSKI M., 2010, Metale ciężkie w wodzie i osadach dennych małego zbiornika wodnego Psurów (Heavy metals in water and sediments of a small reservoir in Psurów), in: *Ochrona Środowiska i Zasobów Naturalnych*, no 42.
6. GEOMOR, 2016, http://www.geomor.com.pl/ (29.10.2016).
7. HAZIK T., CZAPLICKA-KOTASZ A., ŚLUSARCZYK Z., SZALIŃSKA E., 2013, Przestrzenne zmiany stężeń cynku w osadach dennych Zbiornika Czorsztyńskiego (Spatial

variations in zinc concentrations in the sediments of Czorsztyn Reservoir), in: *Inżynieria i ochrona środowiska*, 16(1), p. 57-68.

8. KARWACKA A., NIEDZIELSKI P., STANISZEWSKI R., 2015, Ocena stanu osadów dennych wybranych jezior powiatu poznańskiego (Assessment of sedimentsof selected lakes in Poznań County), in: *Rocznik Ochrona Środowiska/Annual Set Environment Protection* vol. 17, pp. 1684-1698.
9. KAZIMIEROWICZ Z., KAZMIEROWICZ J., 2014, Badania zawartości metali ciężkich w zlewni rzeki Biebrzy i jej trzech dopływów (A study of the heavy metals in the River Biebrz basin and its three tributaries), in: *Inżynieria Ekologiczna* vol. 40, p. 25-32.
10. MIKSCH K., CEMA G., FELIS E., SOCHACKI A., 2015, Nowoczesne techniki i technologie inżynierii środowiska, in: *Rocznik Ochrona Środowiska/Annual Set Environment Protection*, vol. 11, p. 833-857.
11. PAWŁOWSKI A., 2009, Teoretyczne uwarunkowania rozwoju zrównoważonego (Theoretical considerations of sustainable development), in: *Rocznik Ochrona Środowiska/ Annual Set Environment Protection*, vol 11, p. 985-994.
12. PAWŁOWSKI L., 2011, Rola monitoringu środowiska w realizacji zrównoważonego rozwoju (The role of environmental monitoring in the implementation of sustainable development), in: *Rocznik Ochrona Środowiska/ Annual Set Environment Protection* vol. 13, p. 333-346.
13. POLECHOŃSKI R., 2003, Ołów w ekosystemie jeziora Sława – przemieszczanie kumulacja oraz próba bilansu w dziesięcioleciu 1993-2003 (Lead in Lake Sława's ecosystem –cumulation transfer and an attempt for balance in the decade 1993-2003), in: *Zesz. Nauk. Akademii Rolniczej we Wrocławiu* nr 497, *Rozprawy* CCXXIII, Wrocław.
14. ROZPONDEK R., WANCISIEWICZ K., 2016, Analiza rozkładu zanieczyszczeń w osadach dennych z zastosowaniem GIS w przybrzeżnej strefie zbiornika wodnego Ostrowy na rzece Biała Oksza (GIS-based analysis of the distribution of contaminants in the sediments along the shoreline of the Ostrowy Reservoir on the River Biała Oksza), in*: Inżynieria i ochrona środowiska*, vol. 19, no 1, p. 37-49.
15. SOBCZYK W., BIEDRAWA-KOZIK A., KOWALSKA A., 2012, Threats to areas of natural interest, in: *Rocznik Ochrona Środowiska/ The Annual Set Environment Protection*, vol. 14, p. 262-273.
16. TOMCZAK M, 1998, Spatial Interpolation and its Unceratinty Using Automated Anistropic Inverse Distance Weighting (IDW) – Cross-Validation/Jackknife Approach, in: *Journal of Geographic Information and Decision Analysis*, vol. 2, no 2, p. 18-30.
17. VANDECASTEEL B., QUATAERT P., de VOS B., TACK F.M.G., 2004, Assessment of the pollution status of alluvial plains: a case study for the dredged sediment derived soils along the Leie River, in*: Arch. Environ. Contam. Toxicol*, vol. 47, p. 14-22.
18. ZHANG C., SELINUS O., 1998, Statistics and GIS in environmental geochemistry – some problems and solutions, in: *J. Geochemical Exploration*, 64, p. 339-354.

**PROBLEMY EKOROZWOJU – PROBLEMS OF SUSTAINABLE DEVELOPMENT**
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# Ecological Compensation Standard for Non-point Pollution from Farmland

# Propozycja standardu ekologicznej kompensacji dla Obszarowych zanieczyszczeń z rolnictwa

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## Abstract

Non-point source water pollution mainly comes from farmland chemical fertilizers which has become an obstacle of agricultural sustainability and ecological health. As a public policy tool for assessing global ecological crisis and environmental pollution, ecological compensation is important for regional agricultural sustainability. Ecological compensation that farmers receive from governments is based on their reduction of fertilizer application at optimal ecological and economic levels. In this study we estimated the ecological compensation standards for nitrogen non-point pollution in Yixng city with contingent valuation method and cost-benefit method. Results showed that the range of theoretical values of ecological compensation of nitrogen in Yixing City depended upon its optimal ecological and economic nitrogen application levels. The willingness of farmers to accept the compensation was positively correlated with their farming experience and education. There were about half of farmers willing to accept the compensation. Based on the present study, we found Yixing's ecological compensation standard for controlling nitrogen non-point pollution was 620.0 yuan/hm$^2$ at the current economic development level.

**Key words:** ecological compensation standard; nitrogen; non-point pollution; optimal ecological economic nitrogen application amount

## Streszczenie

Obszarowe zanieczyszczeń wód z rolnictwa pochodzą ze stosowania nawozów sztucznych, stanowiących przeszkodę na drodze do osiągnięcia rolniczej zrównoważoności i równowagi ekologicznej. W tym kontekście ekologiczna kompensacja, stanowiąca narzędzie polityczne do oceny kryzysu ekologicznego i ogólnego poziomu zanieczyszczenia środowiska, okazuje się także ważna w wymiarze lokalnej zrównoważoności rolniczej. Wysokość świadczeń, które rolniczy dostają od władz, jest uwarunkowana poziomem redukcji stosowania nawozów, którego celem jest osiągnięcie poziomu optymalnego zarówno zer strony ekologicznej, jak i ekonomicznej. W tym artykule, przy pomocy Metoda wyceny warunkowej i metody kosztów i korzyści, ustaliliśmy standardy ekologicznej kompensacji dla miasta Yixng. Otrzymane rezultaty pozwalają na stwierdzenie, że zakres teoretycznych wartości ekologicznej kompensacji dla azotu w Yixing zależy od ustalenia optymalnych ekologicznych i ekonomicznych pozimów stosowania azotu. Zainteresowanie rolników otrzymaniem odszkodowania okazało się być pozytywnie skorelowane z ich doświadczeniem rolniczym i poziomem wykształcenia. Chęć jego otrzymania zgłosiła połowa z nich. Ustaliliśmy ponadto, że standard ekologicznej kompensacji dla Yixing odnoszący się kontrolowania obszarowych zanieczyszczeń związanych z nawozami azotowymi wynosi 620.0 yuan/hm$^2$ , przy założeniu obecnego poziomu rozwoju ekonomicznego.

**Słowa kluczowe:** standard kompensacji ekologicznej, azot, obszarowe źródła zanieczyszczeń, optymalna ekologicznie ilość stosowanego azotu

## Introduction

Assessment of ecological compensation standards is a core and key to control nitrogen non-point pollution from farmland (Qu, 2007). It significantly contributes to the success or failure of compensation mechanism operation. Therefore, proper approaches to estimate ecological compensation standard have important theoretical and practical significances. Quantitative research on ecological compensation standard for controlling non-point pollution from farmland has matured overseas. Babcosk conducted theoretical and empirical analysis of compensation standard of reducing agrochemicals (Wu, 1996). Stefano used ecosystem services value method to calculate farmland protection compensation standards in Florida around $ 42·hm-2·a-1 (Pagiola, 2008). At present, ecological compensation standard, for controlling agriculture non-point source pollution was studied in general in China, but especially those for farmland nitrogen non-point pollution controlling were not documented well. Ecological compensation standard for controlling agriculture non-point source pollution mainly considered the potential cost for agriculture environment protection or producers' willingness for compensation (Shen et al., 2009; Cai, Zhang, 2011; Pei, 2010). But a crucial problem on reduction of pollutants after ecological compensation implementation, was not clearly answered. However, the ultimate goal of building ecological compensation mechanism was pollutant reduction. Therefore, the pollution control targets must be clearly set before establishing compensation standard for agriculture non-point source pollution. The objectives of this study were to establish ecological compensation standard for controlling nitrogen non-point pollution from farmland by using cost-benefit method and contingent valuation approach. The outcome will benefit preparation of investment budget for controlling agricultural nonpoint source pollution.

## 1. Materials and Methods

### *1.1. Calculation Basis*

Agricultural non-point source pollution stems from the highly negative externalities of production activities. Agricultural producers engage in the production of positive externalities or reducing negative externalities of production activities which lead to control the farmland nitrogen non-point source pollution. However, the ecological construction and environmental protection activities with strong positive externalities often are provided directly by the government as public goods in fact. Faced with a regional increasing agricultural population, it is truly meaningful to consider how to stimulate farmers to decrease the intensity of production by means of compensation or changes in production methods to weaken the negative effects of the external environment (Wang, Cao, 2008). The FAO (FAO, 2007) thought that payments for environmental services is compensation for producers' loss of income due to change of operation to provide different combinations or a higher level of environmental services. In many cases, the payment to producers was in order to reduce the environmental damage caused by the final production decisions. Therefore, the authors suggested that calculation of ecological compensation standard for controlling nitrogen non-point pollution from farmland should take account of reduction of negative external environmental effects as a starting point in term of the farmers' crop production loss. Reducing a certain amount of chemical nitrogen fertilizer protects the farmland ecological environment. The foreign experience on the farmland ecological compensation policy showed that the implementation of agricultural environment goals were also promoted by reduction of negative external effects and application of subsidies (Geiger et al., 2010; Baylisa et al., 2008).

However, what extent nitrogen fertilizers reduce for compensation is of importance. Even though the farmers reduced a considerable amount of nitrogen fertilizer on the original basis, if the final nitrogen fertilizer application amount was not sufficient to achieve the pollution control goals, this action to reduce nitrogen fertilizer was still invalid. The farmers received compensation only if they use no nitrogen or less than the optimal ecological economic nitrogen amount (that is the amount that might balance between ecological protection and economic benefits). In other words, the upper limit of compensation was the net production loss due to use no or less nitrogen fertilizers. The lower limit was the production loss caused by reduction of nitrogen fertilizer to the optimal ecological economic nitrogen application amount. As the net loss due to no or less nitrogen fertilizer use might be estimated under the normal production revenue. Therefore, how to determine optimal ecological economic nitrogen amount is the key to assess ecological compensation standard calculation.

### *1.2. Calculation methods and procedures*

#### *1.2.1. Determination of optimal ecological economic nitrogen amount*

The optimal ecological economic nitrogen amount fertilizer is known as optimal social amount of nitrogen fertilizer. It promotes the agricultural output with reasonable growth and takes into account the farmers' economic benefits, social and ecological environment. At the same time, it leads to low environmental pollution which is not exceeding the regional environmental capacity. On the basis of the traditional agricultural production, it is modelled by bringing external costs into production costs in terms of agricultural technology economics (Lv, Cheng,

2000). Many studies (Mao et al., 1997; Zhang, Cao, 2009; Xiang et al., 2006) have employed a quadratic function on nitrogen inputs in agricultural production. Grain yield function could be built as follows:

$$Y = a + bX - cX^2$$

Where Y was grain yields; X was nitrogen inputs; a, b, c were constants (all are positive numbers). Let V be production value of grains, then V function may be built as follows:

$$V = YP$$

Where Y was grain yields; P was the price of grains. Supposed that the other input factors were fixed (their corresponding costs K were also fixed in process of grain production, the total costs of the grain production (T) might be expressed as:

$$T = K + XP_f$$

Where Pf was the price of nitrogen fertilizer, let the total Profits be W, then W could be expressed as follows:

$$W = V - T = (a + bX - cX^2)P - (K + XP_f)$$

According to the principle of Benefit Maximization and law of Diminishing Returns, when the marginal benefit equals the marginal cost, there will be the maximum benefit; when the resource inputs o-f the marginal profit is equal to zero, there will be the maximum profit, that is

$$dW / dX = bP - P_f - 2cPX$$

Let the nitrogen amount to farmers' maximum economic efficiency be $X_1$, then,

$$X_1 = b/2c - P_f/2cP = (bP - P_f)/2cP$$

If over-application of nitrogen fertilizers resulted in ecological environment pollution and negative externality, external costs should be taken into account as a part of the total social cost of chemical fertilizers when calculated the farmer's fertilizer input costs. Considering nitrogen inputs bringing negative externalities and the welfare of whole society, nitrogen as the cost of investment in the resource elements should include the external costs. While, the marginal social cost of nitrogen fertilizer was expressed as

$$MSC = MPC + MUC + MEC$$

Where *MSC* was the marginal social cost; *MPC* represented the marginal production cost; *MUC* was the marginal utilization cost; *MEC* was the marginal external cost. On the basis of the procedures mentioned above, $X_1$ should be rewriting as

$$X_2 = b/2c - (P_f + MUC + MEC)/2cP$$

Where $X_2$ was the optimal ecological economic nitrogen amount. Compared $X_1$ and $X_2$, we may see, $X_1 > X_2$, and the economic interests of the farmers was damaged in accordance with the principle of decreasing returns. Therefore, in order to protect farmland ecological environment, a certain amount of economic loss compensation must be given to the farmers. This will encourage the farmers to apply nitrogen less than $X_1$ resulting in achieving the purpose of reducing the negative effect of the external.

Solutions of $X_1$ and $X_2$ needed to define the values of *b*, *c*, *P*, $P_f$, *MEC* and *MUC*. The values of *b* and *c* might be solved by regression analysis of the relationship between the chemical fertilizer application and the foodstuff yields per hectare area. *P* and $P_f$ were the market prices of grains and nitrogen fertilizers, regarding the nitrogen fertilizers as no depletion costs (that is *MUC*=0). *MEC* needed to be determined for the solution of $X_2$.

*1.2.2. Determination of external cost of nitrogen fertilizer application*

External costs of nitrogen fertilizer application were extensively studied in China and abroad. Energy analysis was used as means by Lai Li (Lao et al., 2009) to estimate external costs of nitrogen fertilizer application, and external environmental costs of nitrogen fertilizer application. However, there was no unified standards available. Here are the steps in estimation of external cost of N fertilizer application:

(1) Nitrogen pollution classification

Pollution caused by nitrogen implication was divided into three categories, namely, air pollution, soil pollution and water pollution, and processes and environmental impacts of the various types of pollution were determined (Table 1).

(2) Environmental impacts: dose of pollutants

Doses of pollutants of nitrogen fertilizers were estimated and as follows:

$$Dose_i = M \times C \times (W_f / W_c),$$

Where $Dose_i$ was the dose of pollutant *i*; *M* was the amount of pure nitrogen; *C* was circulation coefficient of nitrogen; $W_f$ and $W_c$ was the molecular weight of nitrogen and the pollutant.

Circulation coefficients of nitrogen were dynamic therefore it was monitored dynamically. Values of constant C was estimated from previous published data (Zhu, Sun, 2006; Zhang et al., 2007; De Paz, Ramos, 2004) (Table 1).

(3) Quantification of Environmental impacts

Disability Adjusted Life Year method was used to quantify the environmental impact of air, soil and water, and to estimate the human health effects caused by nitrogen pollutants with the following model:

$$DALY_i = C_{di} \times Dose_i,$$

Where $DALY_i$ was the cumulative years of life damage; $Dose_i$ was the dose of pollutant *i*; and $C_{di}$ was the life damage year caused by per kilogram pollutant and the value of $C_{di}$ was from Eco-indictor 99 (Eco-I=indictor, 1999).

(4)Estimation of total energy cost of environmental impacts

The total energy cost of environmental impacts was the product of unit-labor energy at home and abroad and cumulative years of life damage as follows:

Table 1. Environmental impact processes and circulation coefficient C of farmland nitrogen

| Pollution types | Processes | Environmental Impact | Circulation Coefficient |
|---|---|---|---|
| $NH_3$ | $NH_3$ from nitrogen volatilization | Respiratory impairment | 11% |
| $N_2O$ | $N_2O$ emission in the microbiological trans-formation of nitrogen in soil | Greenhouse effect, destruction of the ozone layer | 0.67% |
| $NO_X$ | Nitrogen oxides produced by microbial nitrification or denitrification | Destruction of the ozone layer, respiratory impairment | 0.50% |
| Soil Pollution | Increase the nitrate content in underground water by nitrogen leaching | Soil salinization | 0.50% |
| $NO_3^-$—N | $NO_3^-$N enriched in surface water | Eutrophication,carcinogenic effect | 2% |
| $NH_4^+$—N | $NH_4^+$—N enriched in surface water | Eutrophication | 5% |

$$U = \sum_{i=1}^{n} Energy_i = \sum_{i=1}^{n} (DALY_i \times C_m)$$

Where $U$ was total energy costs of environmental impact of nitrogen; $Energy_i$ was energy costs of pollutant $i$; $C_m$ was unit-labor energy consumption per year. Its value was 9.35× 1016sej referencing on Odium H T's research data in this paper (Odium, 1996).

(5) Conversion of comprehensive environmental costs

In accordance with energy money ratios of each year in a certain area, comprehensive environmental costs of nitrogen fertilizer application were estimated.

$$E_{rmb} = U / C_g ,$$

Where $E_{emb}$ was the macro-economic value of environmental impact of nitrogen fertilizers, $C_g$ was energy loading per macroeconomic value (this was a ratio of energy value for a country or area in unit time and GDP). The value of $C_g$ of Yixing City was 7.15×1011sej/yuan, which was calculated based on the energy consumption of per unit GDP published in Jiangsu Statistical Yearbook with energy conversion coefficient (Li et al., 2001) and conversion rates of solar values (Wang, Cao, 2008).

*1.2.3. Ecological compensation amount*

According to the discussion above, the farmers might receive the maximum compensation (that was the upper limit of compensation) if they applied no nitrogen and minimum compensation (the lower compensation) when they reduced the nitrogen to the optimal ecological economic nitrogen application amount. If the maximum compensation was $Q_u$, the minimum compensation was $Q_l$, then,

$$Q_u = P \times Y\Big|_{X=X_1} - X_1 P_f = aP - \frac{bPP_f - P_f^2}{2cP}$$

$$Q_l = (P \times Y\big|_{X=X_1} - X_1 P_f) - (P \times Y\big|_{X=X_1} - X_2 P_f) =$$

$$\frac{MUC + MEC}{4cP}(bP - 2bP_f - MEC - MUC)$$

**1.2.4. Determination of ecological compensation standard**

The farmers' willingness of reducing nitrogen and accepting compensation were used to determine the ecological compensation for nitrogen non-point pollution control from farmland via contingent valuation method. Yixing City was the typical farmland nitrogen non-point pollution scenario. A series of questionnaire was designed to survey the farmers' willingness. Determination of the ecological compensation standard was based on the answers of farmers' wishes. A measurement model was built to analyze the factors affecting the farmers' willingness.

(1) Questionnaire design

Contents of survey: ①Basic socio-economic characteristics of the surveyed farmers, including the respondents' gender, age, education level, village cadres or not, agricultural production experience, and family income, main job, and so on. These were used to analyze how socio-economic characteristics of the surveyed farmers affect their willingness of reducing nitrogen fertilizer. ② The surveyed farmers' compensation willingness of reducing nitrogen fertilizers: There was a survey study on whether the farmers are willing to reduce nitrogen fertilizer based on government compensation levels which corresponded their reducing nitrogen amount.

(2) Sampling survey and sample characteristics

After the questionnaire design modification, the survey team carried out investigation in December

2011, by randomly selecting 6 villages in Wanshi town and Zhou tie town in Yixing County. Selection of villages mainly depended upon economic situation, main types of crops, land resource endowment of the village. The farmer personal and household characteristics included sex, age, years of education, household income, the scale of farming, and the main types of work. There were 110 portions of research samples. Among them, 101 were effective, accounting for 91.8% of the total questionnaire. The research village involved, Caodong, Yu zhuang and Wanshi in Wanshi Town, Donghu, Yangxi and Tangxia in Zhou tie town.

Among the responding samples, the male accounted for 60.40% slightly more than the female. The main labor force was middle-aged and elderly who were between 40 to 70 years old, accounting for 91.19% of the total number of samples. About 79.21% of farmers responded contained more than 3 family members were. Farmer education levels were from elementary or junior high school with 29.7% primary school and 49.5% junior high school. About71.79% of farmers' annual household income were more than 20000 yuan. Non-farm families and agricultural household with more than half of the household income accounted for 74.26% and22.77%, respectively.; 95.04% of the households surveyed grew rice and wheat, of which 92.5% applied urea. Peasants with > 20-year farming experience accounting for 81.19% while 68.31% of farmers engaging in farming, and 16.83% with non-agricultural work.

(3) Factors analysis of farmers' willingness of acceptance compensation

Based on age, gender, and education level of farmers, the main types of work, the proportion of farm income of annual household income, farming experience, the scale of planting, the econometric model of *farmers' willingness of reducing nitrogen for compensation* was constructed. The significant factor of decision-making for acceptance compensation was found out.

Multi-factors comprehensively affects farmers' willingness of acceptance compensation. Farmers had only two options of willingness of acceptance compensation: Yes or No. Therefore, this paper reported the main factors of the farmers' willingness of acceptance compensation by constructing a probability model. In this probability model, the dependent variable adopt was explained as whether the farmers were willing to accept compensation. If they were, then adopt was set at 1, otherwise adopt was set at 0. There were nine independent variables, including gender(sex), age(age), education level( edu), village cadre or not(cadre), the farming number in family(numb), proportion of agricultural income(inco), planting experience(expe), farming scale(scale), and the main type of work(job). The profit model was developed as follows:

$$\text{adopt} = \alpha_0 + \alpha_1 \times \text{sex} + \alpha_2 \times \text{age} + \alpha_3 \times \text{edu} + \alpha_4 \times \text{cadre} + \alpha_5 \times \text{numb} + \alpha_6 \times \text{inco} + \alpha_7 \times \text{expe} + \alpha_8 \times \text{scale} + \alpha_9 \times \text{job}$$

## 2. Results and discussion

### *2.1. External costs of nitrogen fertilizer application*

The environmental impact dose of nitrogen was calculated by using the data of used nitrogen fertilizer amount (Wuxi Statistical Yearbook, 2009). Combined with harmful factors for various types of pollutants by using Disability Adjusted Life Years method in Monograph Eco-indictor99, Yixing human health effects of nitrogen fertilizer in 2009 was estimated. Finally, combined with annual energy consumption of per worker and the ratio of energy and money every year, external costs of nitrogen application in Yixing in 2009 was estimated as $1.09\times10^7$yuan (Table 2). The external cost of per kilogram pure nitrogen was 1.11 yuan.

### *2.2. Optimal ecological economic nitrogen amount*

(1) Function analysis of nitrogen amount for major food crops

Regression analysis showed that a quadratic equation well described the relation between the nitrogen fertilizer amount and the grain yields per hectare from 1993 to 2009 in Yixing. The quadratic model with the determination coefficient $R^2$ 0.9135 was successfully developed as follows: $y=-0.0119x^2+11.423x+4183.8$ (Fig.1). This indicated that the nitrogen fertilizer application amount was highly correlated with foodstuff yields per hectare in the studied area.

(2) Optimal economic nitrogen application amount

The constants were derived from the quadratic equation. In equation (6), the solution of $X_1$ only determined P and $P_f$. Wheat and rice were two main crops in this region. Urea was the main fertilizer in Yixing. With the purchase price (P=2.083 yuan per kilogram) and total yields of rice and wheat in 2009, the average price of grains (P) and price of nitrogen fertilizer ($P_f$) were calculated: P= 2.08 yuan per kilogram and $P_f$ =4.06 yuan per kilogram. Yixing's optimal economic nitrogen application amount in 2009 was estimated as 398.002 (kg/hm$^2$). This was close to the economic nitrogen application amount of rice and wheat in south of Jiangsu province (391.1 yuan/kg) (Zhu, Zhang, 2010). This proved that production function obtained with regression analysis could better reflect the relationship between grain yields and the amount of nitrogen fertilizers.

(3) Optimal ecological economic nitrogen application amount

Finally the optimal ecological economic nitrogen application amount in Yixing was developed as this

Table 2. Estimated environmental costs of nitrogen fertilization in Yixing City

| Project | Air pollution | | | Soil pollution | Water Pollution | |
|---|---|---|---|---|---|---|
| | $NH_3$ | $N_2O$ | $NO_X$ | nitrate | $NO_3^-$—N | $NH_4^+$—N |
| Impact dose（t） | 859.1 | 180.9 | 257.73 | 380.46 | 1521.83 | 1104.56 |
| Life damage years of per pollutant dose(kg/a) | $5.10\times10^{-5}$ | $4.00\times10^{-6}$ | $6.79\times10^{-5}$ | $4.90\times10^{-5}$ | $3.05\times10^{-5}$ | $1.67\times10^{-5}$ |
| Cumulative years of life damage（a） | 43.81 | 0.72 | 17.5 | 18.64 | 46.42 | 18.45 |
| Total energy（sej) | $1.09\times10^{19}$ | $6.73\times10^{16}$ | $1.64\times10^{18}$ | $1.74\times10^{18}$ | $4.34\times10^{18}$ | $1.73\times10^{18}$ |
| Macro-economic value（yuan） | $5.73\times10^{6}$ | $9.42\times10^{4}$ | $2.29\times10^{6}$ | $2.44\times10^{6}$ | $6.07\times10^{6}$ | $2.41\times10^{6}$ |

Table 3 the parameters of the Probity Model

| Explanatory Variables | Coefficient | Z Statistical Value |
|---|---|---|
| gender(*sex*) | 0.2548 | 0.57 |
| age(*age*) | -2.1244 | -1.53 |
| education level(*edu*) | 0.891** | 2.62 |
| village cadre or not(*cadre*) | 0.4625 | 0.78 |
| the farming number in a family(*numb*) | -0.7887 | -1.65 |
| proportion of agricultural income(*inco*) | -0.3265 | -0.42 |
| planting experience(*expe*) | 0.6908* | 2.01 |
| farming scale(*scale*) | 0.1454 | 0.4 |
| main type of work(*job*) | -0.1565 | -0.45 |

** at 1% significance level and * at 5% significance level

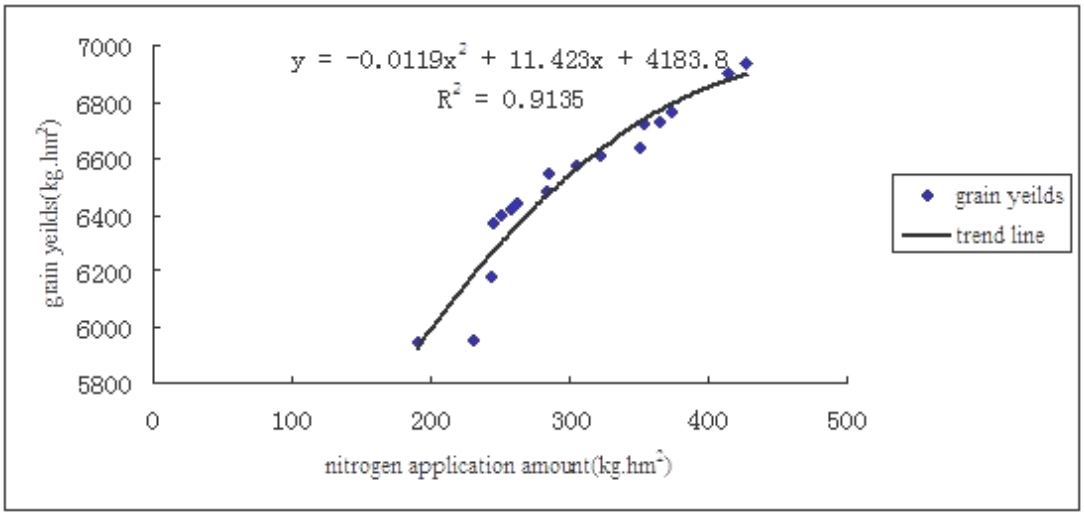


Figure 1 simulated function of grain production in Yixing city

model, $X_2=b/2c（P_f+MUC+MEC）/2cP$. Due to the lack of data, the nitrogen was regarded as no exhaustible resources (*MUC*=0) in this paper. Thus, Yixing's optimal ecological economic nitrogen application amount in 2009 was calculated as 375.61 kg/hm$^2$.

*2.3. Compensation limits*

With values of $X_1$, $X_2$, $a$, $b$, $c$, $P$, and $P_f$, values of $Q_u$ and $Q_l$ were calculated as $Q_u$ 629.4 yuan/hm$^2$ and $Q_l$=7097.7 yuan/hm$^2$.These were the compensation limits of the farmers who participated in farmland nitrogen non-point pollution control in Yixing City (629.4～7097.7 yuan/hm$^2$).

**2**.*4. Compensation standards*

The local governments control farmland nitrogen non-point source pollution to improve regional farmland ecological environment. At same time agriculture production was not sacrificed. Thus nitrogen

application amount for grain production should not be higher than the optimal ecological economic nitrogen application amount and not higher than the target amount. Local farmers were encouraged to reduce the chemical nitrogen application amount voluntarily by constructing good ecological environment – farmland in the Yixing City. Three types of limitation standards (Including the specified amount (375.61 kg/hm$^2$), the target amount(210 kg/hm$^2$) and no nitrogen application) of nitrogen were designed in questionnaire: (1) Less than the target amount (L1); (2) Less than the optimal ecological economic nitrogen application amount (L2); (3) Using manure or organic fertilizer with on chemical nitrogen fertilizer (L3). By using calculation Method of compensation limits discussed above, compensation limits in the case of L1, L2, and L3 are 1746, 620, 7098 yuan/hm$^2$, respectively Famers' willingness with choices of L1, L2, and L3 determined the compensation standard.

The results showed that, 68.31% of the farmers who were visited were willing to accept compensation and reduce nitrogen fertilizer. The farmers' willingness of acceptance of compensation was significantly affected by planting experiences, the farming number of a family, and education levels (Table 3). Both education level and planting experiences significantly and positively affected their willingness. These indicated that the more educated farmers became, the stronger environmental awareness towards the excessive application of nitrogen fertilizers. The more planting experience the farmers had, the more clearly the farmers' understanding the danger of the excessive nitrogen use. The net outcome was that most of farmers will not necessarily seek the higher yields with excessive nitrogen use since it would bring many negative effects such as soil salinization, compaction, and mostly nonpoint source pollution of water body, resulting in increase of production costs. About 50.72% of farmers willing to accept compensation selected L2 while 30.43% selected L1 with 18.85% L3. Since most farmers selected L2 values of compensation in L2 may be considered as Yixing's compensation standards for reducing nitrogen fertilizer. Thus, Yixing's compensation standard for farmland nitrogen non-point pollution control was set as 629.4 yuan/hm$^2$.

*2.5. Discussion*

As a public policy tool to respond to global environmental pollution, ecological compensation has become the environmental and economic policies of Western countries to protect farmland (Zhu, Zhang, 2010). Ecological compensation for agricultural pollution control compensated directly for farmers in order for their developing environmentally friendly agriculture. Compensation standard was determined by negotiation between government and farmers (Wu, Babcock, 1996; Pagiola, 2008). The basis for this compensation was that farmers receive government's compensation based on their reduction in nitrogen fertilization in achieving the optimal ecological economic amount. In this study, optimal ecological economic nitrogen application amount for Yixing City was assessed by using environmental economics and agricultural economics theory. The theoretical value of compensation margin for controlling farmland nitrogen non-point pollution in Yixing City was estimated at 620.0 yuan/hm$^2$. But, there was still further study required for this region. For example, high accuracy of ecological economic nitrogen application amount was based on the shadow price with the reasonable accuracy but not the market price of grains. Therefore further study on estimation of ecological economic nitrogen application amount with the market price of grains were required. In addition, many details were required to develop in the process of compensation implementation, relevant expertise with invited dynamic assessment, and constantly adjustment on the compensation standards in order to maintain the current potentials.

## 3. Conclusion

The successful practice of farmland nitrogen non-point source pollution control had proved that reduction of nitrogen fertilizer was one of the best strategies for controlling nitrogen non-point source pollution from the source. Implementation of ecological compensation may internalize reduction of nitrogen fertilizers. By using contingent valuation method and cost/benefit approach, the ecological compensation standards for controlling farmland nitrogen non-point pollution in Yixing City was estimated. The farmers would be compensated if they reduced the nitrogen fertilizer to the optical ecological economic nitrogen application amount. The optical ecological economic nitrogen application amount for grain production in Yixing was assessed as 375.61 kg/hm$^2$ and the compensation standards for farmland nitrogen non-point pollution controlling was at the rate of 620.0 yuan/hm$^2$ with the theoretical range of 620.0～7097.7 yuan/hm$^2$. About 68.31% farmers responded were willing to accept compensation to reduce nitrogen fertilizers. The farmers' willingness of accepting compensation were significantly affected by farming experiences and educational attainment.

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**References**


1. BABCOCK B.A., 1996, Contract design for the purchase of environmental goods from agriculture, in: *American Journal of Agricultural Economics*, vol. 78, no 4, p. 935-945.
2. BAYLISA K., PEPLOWB S., RAUSSER G., SIMON L,, 2008, Agri-environmental policies in the EU and United States: a comparison, in: *Ecological Economics*, vol. 65, no 4, p. 753-764.
3. CAI Y.Y., ZHANG A.L., 2011, Agricultural land's ecological compensation criteria based on the producers' willingness to accept: a case study of farmer households in Wuhan, in: *Journal of Natural Resources*, vol. 26, no 2, p. 177-189.
4. ECO-INDICATOR99, 2001, *A Damage Oriented Method for Life Cycle Impact Assessment-methodology Annex*, http://www.pre.nl.
5. FAO, 2007, *Foodand agriculture*, http://www.Fao.org/catalog/inter-e.htm (1.09.2016).
6. GEIGER F., BENGSTSSON J., BERENDSE F., WEISSER W.W., EMMERSON M., MORALES M.B., CERYANGIER P., LIIRA J., TSCHARNTKE T, WINQVIST C., EGGERS S, BOMMARCO R, P., BRETAGNOLLE V., PLANTEGEEST M., CLEMENT W., DENNIS C., PALMER C.O. ATE J.J., GUERRERO I., HAWRO V., AAVIK T., THIES C., FLOHRE A., HNKE S., FICCHER C., GOEDHART P.W., INCHAUSTI P., 2010, Persistent negative effects of pesticides on biodiversity and biological control potential on European farmland, in: *Basic and Applied Ecology*, vol. 11, no 2, p. 97-105.
7. LAI L., HUANG X.J., WANG H., DONG Y.H., XIAO S.S., 2009, Estimation of environmental costs of chemical fertilizer utilization in China, in: *Acta Pedologica Sinica*, vol. 46, no 1, p. 64-70.
8. LI S.C., FU X.F., ZHEN D., 2001, Energy analysis for evaluating sustainability of Chinese economy, in: *Journal of Natural Resources*, vol. 16, no 4, p. 297-304.
9. LV Y., CHENG X., 2000, Nitrogen pollution from agricultural non-point sources in lake Tai region and its environmental economic analysis, in: *Shanghai Environmental Science*, vol. 19, no 4, p. 143-146.
10. MAO X.Q., YANG J.R., WANG H.D., 1997, Application of production function model in environmental economic analysis of agricultural production, in: *Journal of Environmental Science*, vol. 17, no 4, p. 480-486.
11. ODUM H.T., 1996, *Environmental Accounting: Emerge and Environmental Decision Making*, Wiley and Sons, New York, p. 100-105.
12. PAGIOLA S, 2008, Payments for environmental services in Costa Rica, in: *Ecological Economics*, vol. 65, no 4, p. 712-724.
13. de Paz J.M., RAMOS C., 2004, Simulation of nitrate leaching for different nitrogen fertilization rates in a region of Valencia (Spain) using a GIS-GLEAMS system, in: *Agriculture, Ecosystems and Environment*, vol. 103, no 1, p. 59-73.
14. PEI Y.H., 2010, *Study on Ecological Compensation Mechanism for Controlling Agricultural Non-Point Source Pollution*, Master thesis, Chinese Academy of Agricultural Sciences, Beijing.
15. QU H., 2007, *Study on Compensation Theory and Approach for Controlling of Agricultural Non-Point Source Pollution*, PhD thesis, Chinese Academy of Agricultural Sciences, Beijing.
16. SHEN G.X., HUANG L.H., QIAN X.Y., PAN D.D., SHI S.G., GULLINO M.L., 2009, Ecological compensation criteria for environmental friendly agriculture production: case study of green agriculture demonstration project in Dongta, in: *Chongming Island Journal of Agro-Environment Science*, vol. 28, no 5, p. 1079-1084.
17. WANG X.Y., CAO L.P., 2008, Subsidy policy for agricultural non-point source pollution control, in : *Water Resource Protection*, vol. 24, no 1, p. 34-38.
18. WA NG H.Y, CAO Z, 2008, *Agricultural Ecology*, Chemical Industry Press.
19. XIANG P.A., ZHOU Y., ZHEN H., YAN H.M., HUANG H., HUANG Q.Y., 2006, Optimal chemical fertilizer application rate accorded with local economic and ecological benefits, in: *Journal of Applied Ecology*, vol. 17, no 11, p. 2059-2065.
20. ZHANG Y.F., CAO W.Z., 2009, Environmental economic analysis in the application of chemical fertilizer, in: *Anhui Agricultural Science Bulletin*, vol. 15, no 2, p. 41-43.
21. ZHANG D.S., SHI X.Z., YU D.S., HUANG B., ZHANO Y.C., HUANG Y., BORN I., LARSSON M., 2007, Numerical simulation of soil nitrogen circling in Peri-urban vegetable farming systems, in: *Acta Pedologica Sinica*, vol. 44, no 3, p. 64-70.
22. ZHU Z.L., ZHANG F.S., 2010, *Basic Research of Mainly Farmland Ecosystem Nitrogen Behaviors and Nitrogen Fertilizer Efficient Use*, Science Press, Beijing.
23. ZHU Z.L., SUN B., 2006, *China's Agricultural Non-point Pollution Countermeasure*, China Environmental Science Press.

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# Sustainable Landfilling as Final Step of Municipal Waste Management System

# Zrównoważone składowiska jako końcowy etap systemu gospodarki odpadami komunalnymi

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## Abstract
This paper discusses the role of sustainable landfilling of municipal waste in the current systems of municipal waste management systems as the manner of final disposal of wastes. The actual data considering share of landfilling as final waste disposal in various countries all over the world allowed to asses importance of this method. Special attention was paid to sustainable landfilling in developing or undeveloped courtiers of low economic incomes. Then, the paradigm of sustainable landfilling was presented and the most effective methods of landfill isolation by liners were discussed. The compacted clay liners were presented as the gainful option for the developing countries. The main determinants of the compacted clay liners' long-term liner sustainability were described as hydraulic conductivity, swell-shrinkage properties and, finally, ability of soil/substrate to sustain its hydraulic conductivity after cyclic drying and rewetting. Finally, possible application of low plasticity clays instead materials of high plasticity, prone to shrinking and swelling, to construction of sustainable compacted earthen liner was underlined.

**Key words:** municipal waste management, sustainable landfilling, compacted clay liners

## Streszczenie
Praca przedstawia znaczenie zrównoważonego składowania odpadów komunalnych jako końcowego etapu ich utylizacji w ramach aktualnych systemów zagospodarowania odpadów komunalnych. W artykule zaprezentowano aktualne dane dotyczące procentowego udziału składowisk w końcowym zagospodarowywaniu odpadów komunalnych w różnych krajach na całym świecie. Zwrócono szczególna uwagę na rolę zrównoważonego składowania odpadów w krajach rozwijających się o niskich dochodach. Następnie zaprezentowano paradygmat zrównoważonych składowisk odpadów oraz przedyskutowano najefektywniejsze metody izolacji składowisk. Zagęszczone przesłony mineralne uznano jako atrakcyjną opcję dla krajów rozwijających się. Opisano najistotniejsze wyznaczniki długoterminowej zrównoważoności i trwałości zagęszczonych przesłon ilastych: przewodnictwo hydrauliczne, charakterystyki skurczu i pęcznienia oraz zdolność gruntu do utrzymania właściwości izolacyjnych po cyklicznym osuszaniu i nawilżaniu. Na koniec przedyskutowano możliwość stosowania iłów o niskiej plastyczności jako materiałów na przesłony mineralne zrównoważonych składowisk odpadów, w miejsce podatnych na skurz i pęcznienie wysokoplastycznych gruntów ilastych.

**Słowa kluczowe:** zarządzanie odpadami komunalnymi, zrównoważone składowisko odpadów, zagęszczone przesłony ilaste

## Landfilling in sustainable municipal waste management system

The idea of sustainable development is usually considered at the three independent but linked pillars: environmental (ecological), social and economic, supported by technical, legal, moral and political aspects (e.g. Pawłowski, 2008). Realization of intergenerational justice guaranteeing the needs of the current and future generations depends to the proper management of water, sewerage, wastes and non-renewable energy carries (Pawłowski L. & A., 2016; Cao et al., 2012; Miksch et al., 2015). Thus, the sustainable development is also directly related to the proper handling of municipal solid wastes (MSW) during the whole process of waste management due to the possible contamination of water, soil and atmosphere, negative changes in the ecosystem, reduction of biodiversity, limiting the economic development and posing a major threat to public health (e.g. Al-Khatib et al., 2010; Othman et al., 2013). Rapid urbanization, quick increase of population and growing consumption may have the detrimental effects on the urban population. The generation of waste is related to the urbanization degree so application of principles of sustainable development to local MSW systems may improve the local ecosystems and their residents' quality of life (Jim, 2013). Thus, the system of sustainable management of solid wastes becomes a major priority of social, legal, economic and ecological/environmental concern, especially in the urbanized areas where large amounts of solid wastes are generated (e.g. Erses Yay, 2015).

The sustainable solid waste management systems include all essential activities related to the wastes collection, shipping and transport, treatment, recycling/reuse and final disposal (e.g. Pires et al., 2011). According to Wilson (1985) a municipal solid waste management has implications on all circles of sustainability, including environmental, social and economic. The generation of wastes and the ability of the society to the waste separation may be related to public/community wealth, social development, environmental and ecological awareness and knowledge (Shekdar, 2009; Guerrero et al., 2013). Transport of wastes from the generators to the treatment plants or the final disposal may be performed by various available means but generally the road transport is being dominant (Eres Yay, 2015). Then wastes may undergo various processes of material and energy recovery and/or volume reduction (e.g. Shekdar, 2009; Franus et al., 2011) including reuse, recycling, composting, bio-fuels production, incineration, pyrolysis, gasification etc. etc. (e.g. Santibanez-Aguilar et al., 2013, Werle and Dudziak, 2014; Suchorab et al., 2016). The final step of municipal solid waste management of remaining wastes, which are unable to be processed by any other measures, is their final disposal by landfilling (e.g. Pires et al., 2011; Othman et al., 2013). The share of landfilling in the recent MSW management for selected countries from different continents presented in Fig. 1 shows a very high differentiation of landfilled municipal wastes percentage. Despite the fact that sanitary landfills are frequently being discouraged in the developed countries, due to leachate seepage and gasses emissions or scarcity of available land etc. (Staszewska and Pawłowska, 2011; Othman et al., 2013), they are in contrast to common practice of the uncontrolled dumping of wastes in the developing countries (Oak-

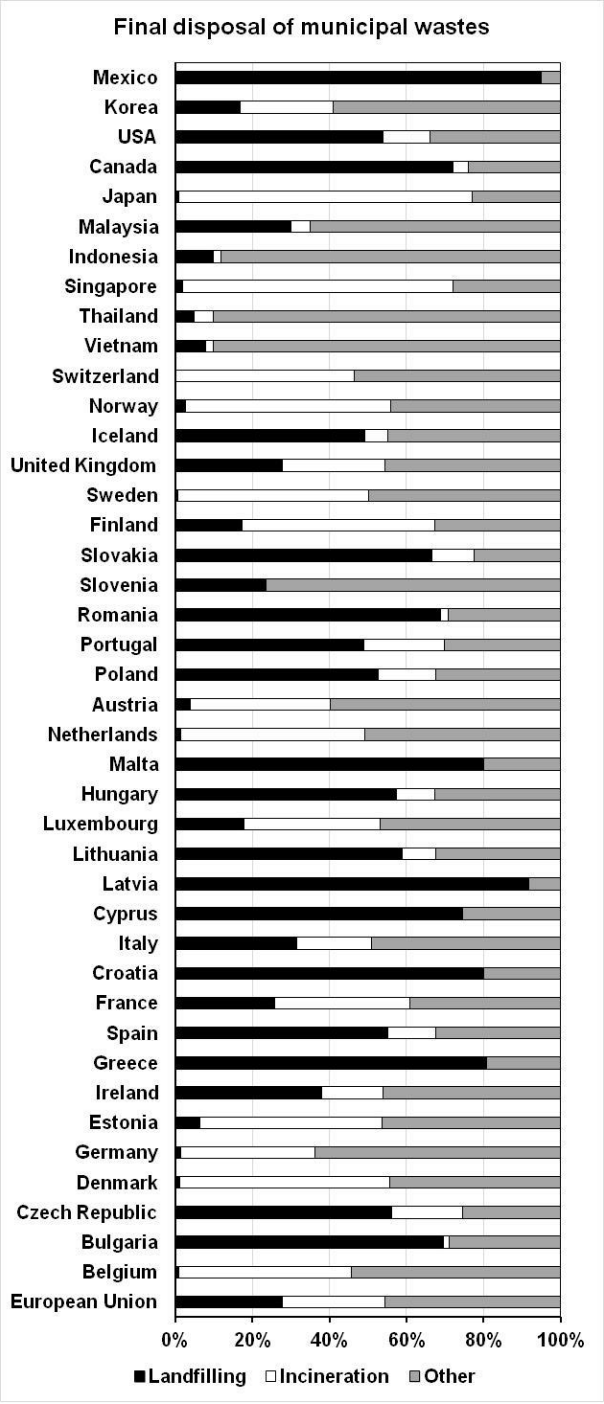


Figure 1. Share of landfilling in the methods of final disposal of wastes in selected countries of the world, combined after Eurostat data (2014), Ngoc and Schnitzer (2009) as well as Eres Yay (2015)

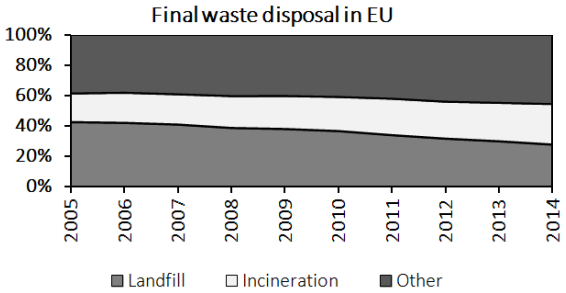


Figure 2. Methods of final waste disposal in the European Union during last decade, developed after Eurostat data

ley and Jimenez, 2012). Landfilling, from the historical point of view was and nowadays remains a dominant cost-effective method of final deposition of the remaining municipal solid waste in many regions (Allen, 2001; Wagner, 2011).

The generally sustainable attitude towards MSW management, based on the several important drivers: public health, environment, resource scarcity and value of wastes, climate change and public concern and awareness are being observed in the developed countries of high economic incomes but the applied practices may vary (e.g. Eres Yay, 2015; Pires et al., 2011; Marshall and Farahbakhsh, 2013). Despite the local differences, the European MSW management systems cover all typical stages: collection, transport, treatment, recycling/reuse and disposal, strictly connected to policies, institutional services, finances, proper technology selection, stakeholders participation and public awareness (Piers et al., 2011). According to Marshall and Farahbakhsh (2013), the current paradigm of sustainable waste management assuming balance between environmental effectives, social acceptability and economic affordability of waste management is commonly accepted in the developed countries.

The historical contribution of various types of final municipal wastes disposal in the European Union during the last decade was presented in Fig. 2. There is a visible decrease in the value of landfilled wastes during the discussed period, from the value of 43% in 2005 to 28% in 2014. Consequently, the share of the other methods of final waste disposal including incineration, increased despite the fact that the presented data included landfilled wastes in the less developed member countries of the EU, which accessed the union in 2004, 2007 and 2013.

Figure 3 shows contribution of landfilling in municipal MSW in the selected Central Europe member countries of the EU, accessed the Union in the XXI century, compared to the European mean value. It is clearly visible, than the decreasing tendency of reduction in the mean landfilling contribution in the EU is accompanied by the similar tendency in most of the new members of the EU, excluding Latvia. Thus, development of new members of the EU during the last decade (see Widomski et al., 2015a) caused the noticeable decrease in the share of landfilling.

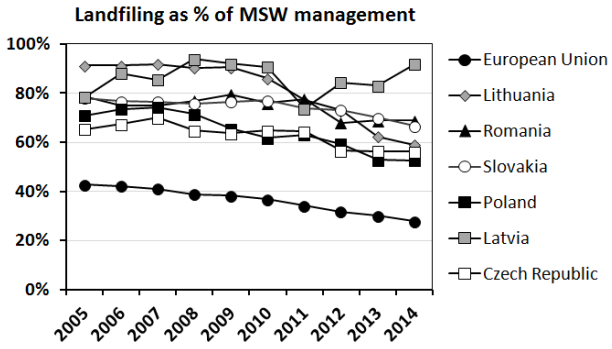


Figure 3. Landfilling as part of MSW management in selected countries of EU, based on Eurostat data

The developing countries of the low economic income in different regions of the globe suffer from a very high municipal waste generation. So, the MSW management becomes a major issue for governments of various levels (national, regional and municipal) and for individuals. Unfortunately, in many cases, the sustainable MSW management systems do not operate properly in many developing countries, regions or cities (e.g. Shekdar, 2009; Zhang et al., 2010; Guerrero et al., 2013; Marshall and Farahbakhsh, 2013). The main reasons for this situation were recognized by Marshall and Farahbakhsh (2013): i) urbanization, inequality and economic growth; ii) cultural and socio-economic aspects; iii) policy, governance and institutional issues; iv) international influence. Moreover, such waste management systems, without any links to sustainability, were accurately characterized by Permana et al. (2015) as *collect, transport and forget*. Exemplary, dos Muchangos et al. (2015) reported that sustainable waste management system failed in Maputo, Mozambique according to uncoordinated or ad hoc efforts and inadequate investments, combined with economic, administrative and technological weaknesses. Similar situation was reported by Al-Khatib et al. (2010) in Palestine where founding constrains, week law enforcement considering wastes collection, transport, treatment and disposal, lack of expertise and appropriate technologies or facilities were noted. Similarly, Zhang et al. (2010) described formal and informal waste collection, low waste separation and recycling ratio, unsatisfactory quality of sanitary landfills, underdeveloped incineration and discharge/levying fees system for the various regions of China. Finally, the high increase in the wastes generation, low municipal budget available, insufficient infrastructure, low quality and technical capacity of technical personnel as well as high costs of MSW management were reported by Permana et al. (2015) for different regions of Indonesia.

The listed above exemplary problems encountered by societies in the developing countries, show that the simple transfer and application of technical and technological remedies from the developed regions will not help to immediately solve the problems related to the inefficient systems of MSW manage-

ment. Since the practical remedies for the North America, Japan or Europe, applied directly in the developing countries may be expensive, complex and complicated. The additional energy consumption, qualified services, workmanship and experienced technical stuff, social and governmental mobilization and support, public awareness may be also required.

Therefore, the final disposal of MSW in the developing countries is generally based on landfilling and open dumping sites. The second method is being commonly recognized as the main and most important source of environmental pollution (e.g. Ngoc and Schitzer, 2009; Shekdar, 2009; Zhang et al., 2010; Guerrero et al., 2013). The reported assessed amount of wastes disposed in the open dumping sites in Southeast Asian countries varied between approx. 50% for Malaysia to 80% in Myanmar and Cambodia (Ngoc and Schitzer, 2009). In the same time, the share of wastes disposed in sanitary landfills varied between 5% for Brunei, Cambodia and Thailand, through 8% for Vietnam, 10% for the Philippines, Myanmar and Indonesia to, finally, 30% for Malaysia. In addition, the open dumping sites creating ecological pressure are commonly localized along the roadsides or close to water bodies, at forest edges or in other environmentally sensitive locations, often without any or with limited measures of operation control and isolation by clay liners or geo-membranes (Shekdar, 2009; Ngoc and Schitzer, 2009; Okot-Okumu and Nyenje, 2011; Oakley and Jimenez, 2012; Guerrero et al., 2013).

It was also reported that municipal landfills in the developing countries are commonly not properly constructed (ineffectively isolated by liners), poorly operated (careless operation and maintenance) and the best practices are unknown or misunderstood (Zhang et al., 2010). The several operational and environmental problems of landfills observed in developing country were reported by Okot-Okumu and Nyenje (2011), including: i) location on wetlands, close to rivers or the other surface waters, on the steep slopes, close to residential areas; ii) not fenced, poor access roads, uncontrolled tipping, fire hazard, high accident risk, landslides, indiscriminate dumping; iii) health hazard, accidents risk, odors, water and soil pollution, erosion. Thus we may state, after Ngoc and Schnitzer (2009) that in the developed countries landfilling is not a difficult problem nowadays, while in medium- and low-income countries or regions, environmental pollution from unsustainable and insufficient landfills is openly complained.

## Sustainable landfilling

Sustainable landfilling may be understood as *the safe disposal of waste within a landfill, and its subsequent degradation to the inert state in the shortest possible time-span, by the most financially efficient method available, and with minimal damage to the environment* (Allen, 2001). The sustainability of landfilling as method of the final waste disposal is crucial in the processes of transaction of goods, understood as availability of resources between the generations, present and future (Wagner, 2011).

The sustainability of landfilling covers most of the circles of sustainable development, including ecologic/environmental, social and economic issues. Nevertheless, potential impacts of capital goods consumption during landfill operation were reported as from low to marginal in relation to the remaining environmental impacts, mainly direct and indirect emissions (e.g. Brogaard et al., 2013). So, the environmental impacts of sustainable landfilling, the threats posed to water and soil, as well as the possible sustainable manner of landfill sealing become the major issue in this paper.

Landfilling of municipal wastes for a significant period of time, even several hundreds of years, poses a major threat to the environment, resulting from biological, chemical and physical processes occurring in the waste body. Impacts of landfilling on the environment was categorized e.g. by Ngoc and Schintzer (2009) and Othman et al. (2013) as: i) contamination of surface water and groundwater by leachate; ii) pollution of soil by direct contact with wastes or leachate percolation; iii) air pollution by products of waste burning; iv) spreading of diseases by birds, insects and rodents; v) bad odors and vi) uncontrolled release of methane by anaerobic decomposition of wastes. Taking into account that the sustainable landfill should pose zero or minimal risk to the environment, the protection of the natural environment and limiting the threats caused by landfill should cover the minimization of leachate generation and seepage, prevention of uncontrolled migration of landfill gas containing greenhouse gases like well-known carbon dioxide (Lou and Nair, 2009) and less often mentioned methane (also very important in greenhouse effect) (Walkiewicz et al., 2016) as well as the reduction in generation and migration of odors (Butt et al., 2008) for the whole period of waste disposal. The main threats to water, soil and groundwater are posed by leachate, the liquid of various composition, taking its constituents from the solid waste body, through which it percolates (e.g. Mukherjee et al., 2014; Brennan et al., 2015). Municipal solid waste landfills produce leachate also after their closure, so the negative impacts of landfills are possible throughout all of this time duration (Brennan et al., 2015). The leachate generation is triggered by the presence of surface water, from precipitations and snow melting, infiltrating to the waste body through the top cover of the landfill. So, inflow and outflow of water to and from the deposited wastes should, in general, be completely prevented by the top and bottom liners. Both liners are often constructed of natural and/or artificial materials of appropriate permeability (Bagchi, 1990; Simon and Müller, 2004; Laner et al., 2012). Generally, the required by the regula-

tions of numerous standards (e.g. EU, 1999; Journal of Laws from 2013 item 523, DepV, 2009) saturated hydraulic conductivity ($K_s$) for the mineral sealing liners, is commonly determined as lower than $1 \cdot 10^{-9}$ m $s^{-1}$. Thus, sustainability of a MSW landfill is in our opinion directly related to the sustainability of its top and bottom liners.

The natural materials like clays, supported by geosyntetics, geomembranes, geonets and geotextiles are commonly used for the construction of liners in the developed countries, but the application of sophisticated sealing materials is often limited in developing countries of low- and medium-income (e.g. Zhang et al., 2010; Pires et al., 2011; Guerrero et al., 2013; Marshall and Farahbakhsh, 2013). Application of clays as construction materials for landfill liners should be verified with regard to their compliance to the local legal standards and the technical engineering guidelines, which are commonly focused on the particle size distribution, saturated hydraulic conductivity, linear shrinkage and the most important geotechnical characteristics such as the Atterberg limits, angle of internal friction, cohesion etc. (e.g. Bagchi, 1990; Daniel and Koerner, 1995; Rowe et al., 1995; Arch, 1998; Wysokiński, 2007). The natural permeability of clay materials, when necessary, especially in construction of top sealing layer, is reduced by an additional compaction (e.g. Benson and Trast, 1995; Simon and Müller, 2004). Compaction of clayey substrates for CCL (compacted clay liner) is usually suggested to be performed for water content wet of optimum (e.g. Wysokiński, 2007). CCLs, on one hand are relatively cheap and utilize the local materials, however they show some serious disadvantages related to compaction effects depending on the applied energy and the molding conditions. They are prone to swelling, shrinkage and cracking, they are also sensitive to cyclic drying and wetting (Benson and Trast, 1995; Allen, 2001; Simon and Müller, 2004; Whalley et al., 2012; Bello, 2013; Widomski, 2016a). Geomembranes (HDPE-GMs), on the other hand, present significant sealing capabilities, creating nearly absolute long lasting barrier for water and gas flow when properly installed and certified. But their certified installation requiring workmanship and state-of art technology is rather costly. They may also become pervious to water and gas, due to faults resulting from material, base preparation, workmanship, earth-works, waste loads and piping installation. Moreover, low heat isolation of HDPE may seriously affect the landfill gas generation in cold weather and cause desiccation of compacted clay liner and cracks formation below HDPE geomembrane. There were also reported liner failure due to interface between various artificial liner layers (Simon and Müller, 2004; Chen et al., 2011; Capaccioni et al. 2011; Hewitt and Philip, 1999; Benson et al., 2012). Finally, geosythetic clay liners (GCLs) are easy transportation and installation, cost-effective and space saving alternatives for CCLs. But their sustainability may be reduced by possible desiccation cracking of highly expansive bentonite, limited long-term shear strength on steep slopes leading to low sliding stability of the cover system, aging affecting strength parameters and limited resistance to roots penetration (Bouazza, 2002; Simon and Müller, 2004; Müller et. al, 2008; Mitchell et al. 1990; Stark et al., 1996; Chang, 2005; Benson et al., 2012). Taking into consideration all the advantages and disadvantages of the discussed different groups of sealing materials, we may state that compacted clay liners, alone or combined with the artificial membranes, despite their drawbacks, are still a worthwhile option, especially in developing countries of medium or low incomes. They can be adopted in various local conditions as easier in installation and maintenance, may utilize local mineral materials, equipment, workmanship and technologies. On the contrary, application of certified artificial liners in the less developed countries requires transfer of know-how, technical support, qualified staff and monitoring system seem to obtained the long-term appropriate performance. However, in many cases the requirements for the successful application of artificial sealings may not fit the principles of sustainable landfilling.

**Determinants of sustainable compacted clay liner**

If a sustainable landfilling is to be understood as safe disposal of municipal wastes, by the most financially efficient method available, with the minimal threat to the environment, long after closure of the landfill, the sealing capabilities of the bottom and top liners, based on CCLs, should be sustained for the similar time duration. In our opinion, the long-term performance of a sustainable landfill liner reducing the environmental impacts of deposited wastes depends on three interrelated properties of the applied soil/substrate, i.e. hydraulic conductivity, swell-shrinkage properties and resulting cracking as well as, finally, ability of soil/substrate to sustain its hydraulic conductivity after cyclic changes of saturation, frequently understood as several cycles of drying and rewetting (shrinkage and swelling).

The saturated hydraulic conductivity of natural clays, containing significant number of fine particles and clay minerals content, is generally assessed as low or very low (e.g. Benson and Trast, 1995) but in many cases the additional compaction may be necessary. The influence of the compaction process on hydraulic properties (including saturated hydraulic conductivity) of clays is non-uniform, in relation to clay soil composition, Atterberg limits and molding conditions (e.g. Mitchell et al., 1965; Benson and Trast, 1995; Rowe et al., 1995; Whalley et al., 2012; Bello, 2013). The clay substrates of high clay or fine (clay+silt) particles and clay minerals content and more plastic, of higher liquid limit or plasticity index, compacted at higher initial water contents allow

lower values of saturated hydraulic conductivity (Benson and Trast, 1995). In short, clayey specimens compacted dry of optimum would have greater hydraulic conductivity than specimens of the same substrate, compacted wet of optimum (e.g. Mitchell et al., 1965; Benson and Trast, 1995, Bello, 2013).

Fine textured soils like clays, or even some sandy soils containing fines, present significant expansiveness, i.e. volume changes due to changes in water content (e.g. Basma et al., 1996; Kalkan, 2011), they increase their volume (swell) when saturated and reduce their volume (shrink) when dewatered (Basma et al., 1996). Hydraulic conductivity of the soils cracked after shrinkage may be greater by several orders of magnitude if compared to uncracked soils of the same type (e.g. Boynton and Daniel, 1985; Albrecht and Benson, 2001). Increased fines content and the applied greater molding water content results in increased cracking, while, on contrary, for the decreased fine particles content, lower cracking appears (Holtz and Kovacs, 1981; Mitchell, 1993; Yesiller et al., 2000). Thus, to avoid significant cracking it was also suggested to perform the compaction of clays at low water contents, dry of the optimum of Proctor curve, where shrinkage potential is definitely lower, despite the expected increased swell (e.g. Daniel and Wu, 1993; Yesiller et al., 2000; Widomski et al., 2015b). The addition of coarse-grained material may reduce the cracking but it may also affect, to some extent, hydraulic and engineering properties of soil (Yesiller et al., 2000), however, reaching the very low values of saturated hydraulic conductivity ($10^{-10}$–$10^{-12}$ m s$^{-1}$) of sand-clay mixture was reported by e.g. Ebina et al. (2004). Thus, it is possible to obtain the clayey substrate containing coarse material of limited shrinkage and significant sealing capabilities improving sustainability of the compacted clay liner. Additionally, swelling and shrinkage, changing the unsaturated and saturated hydraulic conductivity, are irreversible processes so soils or substrates specimens once swelled or shrinked are generally unable to return to their initial characteristics (Holtz and Kovacs, 1981). Cracks, once appeared, are always available in the compacted specimen, even after rewetting and swelling of soil (as long as no additional molding is being applied (Yesiller et al., 2000). The significant increase in the $K_s$ was observed for high plasticity fine soils compacted wet of optimum after several wetting and drying cycles, even to the level typical for the coarse sandy soils (Widomski, 2016a,b). On the contrary, lower changes after several shrink-swell cycles were noted for specimens compacted at dry of optimum water contents. Moreover, it was also observed that the hydraulic conductivity before drying-wetting tests for low plastic clays tested was comparable for both dry and wet sides of Proctor curve, while after the first drying and wetting cycle it increased and remained nearly constant (Widomski, 2016a). So, in our opinion, the long-term self-sustainability of a clay sealing layer may be questionable and may be significantly influenced by the proper selection of the material.

The main and general statutory requirement for material selection is commonly related only to the final demanded saturated hydraulic conductivity, usually below $1 \cdot 10^{-9}$ m s$^{-1}$ (EU, 1999; Journal of Laws from 2013 item 523, DepV, 2009). But, as it was described earlier, the sole saturated hydraulic conductivity is insufficient to ensure the durability and sustainability of compacted clay liners.

Numerous guidelines presenting criteria for a clay material selection, applicable for the compacted clay liner construction, generally allow, or even in some cases favor, high plasticity clays of significant content of fine (clay+silt) particles (e.g. Bagchi, 1990; EPA, 1993; Daniel and Koener, 1995; Rowe at al., 1995; Arch, 1998; Wysokiński, 2007). But, as it was mentioned before, such high plasticity clay materials are typically characterized by the significant shrinkage potential, irreversible desiccation cracking after water content drops below the plastic limit and week resistance to cyclic drying and rewetting, causing increase in hydraulic conductivity by several orders of magnitude. So, the long-term durability and sustainability of the compacted clay liners constructed of the high plasticity clays may be at least questionable. In our opinion, the low plasticity clays allowing the appropriate value of saturated hydraulic conductivity after compaction, containing significant share of coarse sand fraction and showing the considerably lower shrinkage potential, lower plasticity and better resistance to cyclic of drying and rewetting should not be discouraged from application in the construction of compacted clay liners (Widomski, 2016a). It was also reported by Widomski (2016a) that compacted low plasticity clays have no negative effect on the hydraulic efficiency of bottom and top liners of municipal waste landfills.

## Summary

The main purpose of sustainable waste management system is to minimize the negative environmental, social and economic effects of waste generation, transport, treatment and final disposal. As it was presented and discussed in the paper, landfilling plays still an important role as a manner of final disposal of wastes unsuitable to be further reduced, reused or recycled, especially in the developing countries. In case of undeveloped countries of unregulated municipal waste management and dominant open dumping of wastes, sustainable landfilling, economically and socially accepted and efficient in limiting the environmental threats, is a forward-looking and attractive option. However, meeting the requirements of sustainable landfill paradigm assuming deposition of wastes, their subsequent degradation by the cost effective methods with the minimal damage to the environment may be a difficult task, especially during

the lifetime of one generation. Thus, the long-term efficiency of landfill isolation, preventing or significantly reducing the environmental threats posed by municipal landfill to the natural environment is a crucial issue. There are several known, more or less sophisticated manners of landfill isolation, but compacted clay liners utilizing natural materials of a very low conductivity are still a worthy option, especially for local communities of undeveloped or developing regions. But sustainability of landfills isolated by the CCLs may be significantly limited by characteristics of clays which are generally expansive, prone to swelling and shrinkage, undergoing cracking and showing limited resistance to cyclic changes of their moisture conditions. All the above phenomena are related to, or triggered by subtests' particle composition, clay, silt fraction as well as clay minerals content, plasticity and molding conditions. High plasticity clay materials compacted wet of optimum, containing high share of clay fraction and expansive clay minerals, prone to shrinkage, swelling and cracking, despite showing a very low saturated conductivity are often unable to secure the required sealing properties for a prolonged period after landfill closure. So, in our opinion, clay material particle composition and the applied molding water content should be selected very carefully to avoid extensive shrinkage, cracking and increase in hydraulic conductivity of the compacted liner. Moreover, high plasticity clays, prone to desiccation cracking and shrinkage, should be avoided and if possible replaced by substrates containing coarse fraction and presenting lower plasticity, which may allow to retain at least partial sealing capabilities and should improve the sustainability of the compacted clay liner.

## References


1. ALBRECHT B.A., BENSON, C.H., 2001, Effect of desiccation on compacted natural clay, in: *Journal of Geotechnical and Geoenvironmental Engineering* vol. 127, no 1, p. 67-75.
2. AL-KHATIB I.S., MONOU M., ABU ZAHRA A.S.F., SHAHEEN H.Q., KASSINOS D., 2010, Solid waste characterization, quantification and management practices in developing countries. A case study: Nablus district – Palestine, in: *Journal of Environmental Management*, vol. 97, p. 1131-1138.
3. ALLEN A., 2001, Containment landfills: the myth of sustainability, in: *Engineering Geology*, vol. 60, p. 3-19.
4. ARCH J., 1998, Clay barriers in landfills, in: *Environmental interactions of clays. Clays and environment,* eds. Parker A., Rea J.E., Springer, Berlin, Germany.
5. BAGCHI A., 1990, *Design, construction and monitoring of sanitary landfill*, John Wiley & Sons, New York, USA.
6. BASMA A.A., AL-HOMOUD A.S., MALKAWI A.I.H., AL-BASHEBSHEH M.A., 1996, Swelling-shrinkage behavior of natural expansive clays, in: *Applied Clay Science*, vol. 11, p. 211-227.
7. BELLO A.A., 2013, Hydraulic conductivity of three compacted reddish brown tropical soils, in: *KSCE Journal of Civil Engineering*, vol. 17, no 5, p. 939-948.
8. BENSON C.H., EDIL T.B., WANG X., 2012, Evaluation of a final cover slide at landfill with recalculating leachate, in: *Geotextiles and Geomembranes*, vol. 35, p. 100-106.
9. BENSON C.H., TRAST J.M., 1995, Hydraulic conductivity of thirteen compacted clays, in: *Clays and Clay Materials*, vol. 46, no 6, p. 669-681.
10. BOUAZZA A., 2002, Geosynthetic clay liners, in: *Geotextiles and Geomembranes*, vol. 20, p. 3-17.
11. BOYNTON S.S., DANIEL D.E., 1985, Hydraulic conductivity tests on compacted clay, in: *ASCE Journal of Geotechnical Engineering*, vol. 111, no 4, p. 465-478.
12. BRENNAN R.B., HEALY M.G., MORRISON L., HYNES S., NORTON D., CLIFFORD E., 2016, Management of landfill leachate: The legacy of European Union Directives, in: *Waste management*, vol. 55, p. 355-363.
13. BROGAARD L.K., STENTSOE, S., WILLUMSEN, H.C., CHRISTENSEN T.H., 2013, Quantifying capital goods for waste landfilling, in: *Waste management Resources,* vol. 31, p. 555-598.
14. BUTT T.E., LOCKLEY E. and ODUYEMI K.O.K., 2008 Risk assessment of landfill disposal sites – State of the art, in: *Waste Management*, vol. 28, p. 952-964.
15. CAO Y., PIECUCH I., 2012, The Role of State in Achieving Sustainable Development in Human Capital, Technology and Environmental Protection, in: *Rocznik Ochrona Środowiska/ Annual Set Environment Protection*, vol. 14, p. 214-328.
16. CAPACCIONI B., CARAMIELLO C., TATANO F., VISCIONE A., 2011, Effects of temporary HDPE cover on landfill gas emissions: Multiyear evaluation with the static chamber approach at an Italian landfill, in: *Waste Management*, vol. 31, p. 956-965.
17. CHANG M., 2005, Three-dimensional stability analysis of the Kettleman Hills landfill slope failure based on observed sliding-block mechanism, in: *Computers and Geotechnics*, vol. 32, p. 587-599.
18. CHEN Z., GONG H., ZHANG M., WU W., LIU Y., FENG J., 2011, Impact of using high-density polyethylene geomembrane layer as landfill intermediate cover on landfill gas ex-

traction, in: *Waste Management*, vol. 31, p. 1059-1064.
19. DANIEL D.E. and KOERNER R.M., 1995, *Waste containment facilities. Guidance for Construction, Quality Assurance and Quality Control of Liner and Cover Systems*, ASCE Press, New York, USA.
20. DANIEL D.E., WU Y.K., 1993, Compacted clay liners and covers for arid sites, in: *Journal of Geotechnical Engineering, ASCE*, vol. 119, no 2, p. 223-237.
21. DepV, 2009, *German landfill ordinance*, Deponieverordnung.
22. DOS MUCHANGOS L.S., TOKAI A., HANASHIMA A., 2015, Analyzing the structure of barriers to municipal solid waste management policy planning in Maputo city, Mozambique, in: *Environmental Development*, vol. 16, p. 76-89.
23. EBINA T., MINJA J.A., NAGASE T., ONODERA Y., CHATTEREJE A., 2004, Correlation of hydraulic conductivity of clay-sand compacted specimens with clay properties, in: *Applied Clay Science*, vol. 26, p. 3-12.
24. EPA, 1993, *Solid waste disposal facility criteria*, Technical manual 530-R-93-017, US Environmental Protection Agency.
25. ERSES YAY A.S., 2015, Application of life cycle assessment (LCA) for municipal solid waste management; a case study of Sakarya, in: *Journal of Cleaner Production*, vol. 94, p. 284-293.
26. EU, 1999, *Council Directive 99/31/EC of 26 April 1999 on the landfill of waste*, Brussels, Council of the European Union.
27. FRANUS W., FRANUS M., LATOSINSKA J.N., WOJCIK R., 2011, The use of spent glauconite in lightweight aggregate production. *Boletin de la Sociedad Espanola de Ceramica y Vidrio*. vol. 50, p. 193-200.
28. GUERRERO L.A., MAAS G., HOGLAND W., 2013, Solid waste management challenges for cities in developing countries, in: *Waste Management*, vol. 33, p. 220-232.
29. HEWITT P.J., PHILIP L.K., 1999, Problems of clay desiccation in composite lining systems. *Engineering Geology*, vol. 55, p. 107-113.
30. HOLTZ R.D., KOVACS W.D., 1981, *An introduction to geotechnical engineering*, Prentice Hall, Englewood Cliffs, NJ, USA.
31. JIM C.Y., 2013, Sustainable urban green strategies for compact cities in developed and developing economies, in: *Urban Ecosystems*, vol. 16, p. 741-761.
32. Journal of Laws from 2013 item 523, 2013, *Regulation of the Minister of Environment of 30 April 2013 about landfilling of wastes* (in Polish). Sejm of the Republic of Poland, Warsaw, Poland.
33. KALKAN E., 2011, Impact of wetting-drying cycles on swelling behavior of clayey soils modified by silica fume, in: *Applied Clay Science*, vol. 52, p. 345-352.
34. LANER D., CREST M., SCHRAFF H., MORRIS J. W. F. and BARLAZ, M. A., 2012, A review of approaches for the long-term management of municipal solid waste landfills, in: *Waste Management*, vol. 32, p. 498-512.
35. LOU W.F., NAIR J., 2009, The impact of landfilling and composting on greenhouse gas emission – A review, in: *Bioresource Technology*, vol. 100, p. 3792-3798.
36. MARSHALL R.E., FARAHBAKHSH K., 2013, Systems approaches to integrated solid waste management in developing countries, in: *Waste Management*, vol. 33, no 4, p. 988-1003.
37. MIKSCH K., CEMA G., FELIS E., SOCHACKI A., 2015, Nowoczesne techniki i technologie inżynierii środowiska, in: *Rocznik Ochrona Środowiska/Annual Set Environment Protection*, vol. 11, p. 833-857.
38. MITCHELL J., HOOPER D., CAMPANELLA R., 1965, Permeability of compacted clay, in: *Journal of Soil Mechanics and Foundation Division*, vol. 91, p. 41-65.
39. MITCHELL J., SEED R., SEED, H., 1990, Kettleman Hills Waste Landfill Slope Failure. In: Liner-System Properties, in: *ASCE Journal of Geotechnical Engineering*, vol. 116, no 4, p. 647-668.
40. MITCHELL J.K., 1993, *Fundamentals of soil behavior*, Wiley, New York.
41. MUKHERJEE S., MUKHOPADHYAY S., HASHIM M.A., SEN GUPTA, B., 2014, Contemporary environmental issues of landfill leachate: assessment and remedies, in: *Critical Reviews in Environmental Science and Technology*, vol. 45, no 5, p. 472-590.
42. MÜLLER W., JAKOB I., SEEGER A., TATKY-GERTH R., 2008, Long-term shear strength of geosynthetic clay liners, in: *Geotextiles and Geomembranes*, vol. 26, p. 130-144.
43. NGOC U.N., SCHNITZER H., 2009, Sustainable solutions for solid waste management in Southeast Asian countries, in: *Waste Management*, vol. 29, p. 1982-1995.
44. OAKLEY S.M., JIMENEZ R., 2012, Sustainable sanitary landfills for neglected small cities in developing countries: The semi-mechanized trench method from Villanueva, Honduras, in: *Waste Management*, vol. 32, p. 2535-2551.
45. OKOT-OKUMU J., NYENJE R., 2011, Municipal solid waste management under decentralisation in Uganda, in: *Habitat International*, vol. 35, p. 537-543.
46. OTHMAN S.N., NOOR Z.Z., ABBA A.H., YUSUF R.O., 2013, Review of life cycle assess-

ment of integrated solid waste management in some Asian countries, in: *Journal of Cleaner Production*, vol. 43, p. 251-262.
47. PAWŁOWSKI A., 2008, How many dimensions does sustainable development have?, in: *Sustainable Development*, vol. 16, no 2, p. 81-92.
48. PAWŁOWSKI L. PAWŁOWSKI A., 2016, Wpływ sposobów pozyskiwania energii na realizację paradygmatów zrównoważonego rozwoju, in: *Rocznik Ochrona Środowiska/Annual Set Environment Protection*, vol. 18, no 2, p. 19-37.
49. PERMANA A.S., TOWOLIOE S., AZIZ N.A., HO C.S., 2015, Sustainable solid waste management practices and perceived cleanliness in a low income city, in: *Habitat International*, vol. 49, p. 197-205.
50. PIRES A., MARTINHO G., CHANG N.-B., 2011, Solid waste management in European countries: A review of system analysis techniques, in: *Journal of Environmental Management*, vol. 92, p. 1033-1050.
51. ROWE R.K., QUIGLEY R.M., BOOKER J.R., 1995, *Clayey barrier systems for waste disposal facilities*, E & FN SPON, London, UK.
52. SANTIBANEZ-AGUILAR J.E., PONCE-ORTEGA J.M., GONZALEZ-CAMPOS J.B., SERNA-GONZALEZ M., EL-HALWAGI M.M., 2013, Optimal planning for the sustainable utilization of municipal solid waste, in: *Waste Management*, vol. 33, p. 2607-2622.
53. SHEKDAR A.V., 2009, Sustainable solid waste management: an integrated approach for Asian countries, in: *Journal of Waste Management*, vol. 29, p. 1438-1448.
54. SIMON F.G., MÜLLER W.W., 2004, Standard and alternative landfill capping design in Germany, in: *Environmental Science & Policy*, vol. 7, p. 277-290.
55. STARK T.D., WILLIAMSON T.A., EID H.T., 1996, HDPE geomembrane/geotextile interface shear strength, in: *Journal of Geotechnical Engineering*, vol. 122, no 3, p. 197-203 .
56. STASZEWSKA E., PAWLOWSKA M., 2011, Characteristics of Emissions From Municipal Waste Landfills, in: *Environment Protection Engineering*, vol. 37, p. 119-130.
57. SUCHORAB Z., BARNAT-HUNEK D., FRANUS M., LAGOD G., 2016, Mechanical and Physical Properties of Hydrophobized Lightweight Aggregate Concrete with Sewage Sludge, in: *Materials*, vol. 9, no. 5, Art. No. 317.
58. WAGNER J., 2011, Incentivizing sustainable waste management, in: *Ecological Economics*, vol. 70, p. 585-594.
59. WALKIEWICZ A., BULAK P., BRZEZIŃSKA M., WNUK E., BIEGANOWSKI A., 2016, Methane oxidation in heavy metal contaminated Mollic Gleysol under oxic and hypoxic condition, in: *Environmental Pollution*, vol. 213, p. 403-411.
60. WERLE S., DUDZIAK M., 2014, Gaseous fuels production from dried sewage sludge via air gasification, in: *Waste Management & Research*. vol. 32, p. 601-607.
61. WHALLEY W.R., MATTHEWS G.P., FERRARIS S., 2012, The effect of compaction and shear deformation of saturated soil on hydraulic conductivity, in: *Soil & Tillage research*, vol. 125, p. 23-29.
62. WIDOMSKI M.K., GLEŃ, P., ŁAGÓD G., JAROMIN-GLEŃ K., 2015a, Sustainable development of one of the poorest province of the European Union: Lublin Voivodeship, Poland – attempt of assessment, in: *Problemy Ekorozwoju/ Problems of Sustainable Development*, vol. 10, no 2, p. 137-149.
63. WIDOMSKI M.K., STĘPNIEWSKI W., HORN R., BIEGANOWSKI A., GAZDA L., FRANUS M., PAWLOWSKA M., 2015b, Shrink-swell potential, hydraulic conductivity and geotechnical properties of two clay materials for landfill liner construction, in: *International Agrophysics*, vol. 29, p. 365-375.
64. WIDOMSKI M.K., 2016a, *Sustainability of compacted clay liners and selected properties of clays*, Monographs vol. 127, Komitet Inżynierii Środowiska PAN, Lublin.
65. WIDOMSKI M.K., STĘPNIEWSKI W., HORN R., 2016b, Sustainability of Compacted Clays as Materials for Municipal Waste Landfill Liner,, in: *Rocznik Ochrona Środowiska/Annual Set Environment Protection*, vol. 18, no 2, p. 249-257.
66. WILSON D.C., 1985, Long-term planning for solid waste management, in: *Waste Management & Research*, vol. 3, no 3, p. 203-216.
67. WYSOKIŃSKI L. (ed.), 2007, *Principles of assessing the suitability of cohesive soils of Poland for the construction of mineral insulating barriers* (in Polish), ITB, Ministry of Environment, Warsaw, Poland.
68. YESILLER N., MILLER C.J., INCI G., YALDO K., 2000, Desiccation and cracking of three compacted landfill liner soils, in: *Engineering Geology*, vol. 57, p. 105-121.
69. ZHANG D.Q., TAN S.K., GERSBERG R.M., 2010, Municipal solid waste management in China: Status, problems and challenges, in: *Journal of Environmental Management*, vol. 91, p. 1623-1633.

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