African Journal of Business Management Vol.5 (28), pp. 11386-11398, 16 November, 2011
Available online at http://www.academicjournals.org/AJBM
DOI: 10.5897/AJBM11.225
ISSN 1993-8233 ©2011 Academic Journals

Full Length Research Paper

Sustainable technology management indicators: Objectives matrix approach

Maja Todorovic, Maja Levi Jaksic, and Sanja Marinkovic*

Department of Technology, Innovation and Development Management, Faculty of Organizational Sciences, Belgrade, Serbia.

Accepted 24 August, 2011

In this paper, the concept of sustainable development is viewed in the perspective of the relations, influences and interactions in the spheres of technology management and natural resource development. The managerial methods, techniques and tools strongly rely on the measurement capacities and on the support of sustainability performance indicators. This paper, hence, focuses on the identification of the set of sustainability indicators at the macro level of national economy. They have been identified according to their social, economic, industrial and ecological dimensions, the priorities set by their contribution to technological development. The elaborated set of sustainability indicators are at the base of the Objectives matrix model (OMM), additionally equipped with the borders and goals determined by ecological rationality and technological policy of sustainable development. The model is empirically tested with concrete data on air quality in Serbia, while the benchmark indicator values had been drawn from Denmark. The results obtained by implementing the OMM in Serbia represent a base for valuable conclusions. The cause-consequential interaction of technological development and natural resources shows the importance of an integral, holistic approach introducing a new concept of sustainable technology management.

Key words: Technology management, sustainable development, indicators, objectives matrix model.

INTRODUCTION

The concrete dimensions of sustainable technology management and development represent the basis for sustainable development of the economy and society. Technology management deals with the crucial decisions concerning: a) the output to be offered in terms of products and/or services, b) inputs and resources necessary to be engaged in manufacturing products and delivering services, c) location of the facilities, and d) developing processes and operations in support of business goals. Crucial responsibility and starting point for sustainable development lies within technology management, with emphasis on the importance of actions and guidance provided in the external environment - legal, economic, political, social and technological, in achieving sustainability goals. Managing technological dynamics lies at the core of sustainable competitiveness of business operations.

The United Nations Division for Political Coordination and Sustainable Development (DPCSD) in its approach to sustainability, observes society as a dynamic system, attributively characterized and determined by four dimensions: sociological, economic, institutional and ecological. The focus of such an approach is to reflect economic, sociological and institutional dimensions of sustainability at equal plane with ecological problems. It enables the determination of relationships - possible synergies and crucial conflicts between different aspects of sustainable society.

Economies and societies in transition focus on a set of specific aspects of sustainability critical to their efficient

*Corresponding author. E-mail: marinkovic.sanja@fon.rs. Tel: +381 11 3950 879, +381 69 8893 176. Fax: +381 11 2461 221.

Abbreviations: OMM, Objectives matrix model; **SD,** sustainable development; STMD, sustainable technology management and development.

and effective transformation. The complexity of the transitional processes is defined by radical changes occurring in the domain of privatization, intensive technological change, restructuring, business strategy and competitiveness, developing markets and infrastructure with the overall concern for the well being of all the actors, environmental issues, satisfaction of all stakeholders - employees, customers, society, etc. Creating the sustainable and feasible development strategy takes into account the diversified needs and goals and strongly relies on the effort to evaluate the internal strengths and resources from the perspective of their competitive capacity. Traditionally, valuable, rare, non-substitutable and non-imitable resources represent key factors that create and maintain an advantageous position with respect to competitors. (Barney, 2004) The sustainable development perspective adds the sustainability as the fifth significant resource attribute.

The success of reforms in countries in transition greatly depends on the quality of management, its structure, definition of organizational roles and processes and tasks assigned to social actors at different levels (Spangenberg, 1998).

The core objectives of sustainable society, as defined so far in the political and scientific discourse, include greater social cohesion, more and better jobs (social dimension), economic competitiveness and stability (economic dimension), declining resource use and economic development, safeguarding biodiversity and ecosystem health (environmental dimension); and an open, participatory approach based on equality and non-discrimination, justice and solidarity (institutional dimension). These specifics are, to a large extent, already a part of the sustainable society models. Building and maintaining such a system requires that policies and strategies are developed based upon these principles and resulting in a mixed economic system justified by "value mix": based on a market economy with its inherent drive towards efficient and productive resource allocation, but correcting the distributional (social), environmental and institutional blindness of the market by means of public policies. How the state, the market and the civil society interact, is crucial for every model, be it positive or negative (Spangenberg, 2002).

SUSTAINABLE TECHNOLOGY MANAGEMENT AND DEVELOPMENT PRINCIPLES

Sustainable competitiveness means the achievement of a set of different goals – economic and non-economic, meaning that it is a concept based on quantitative and qualitative performance indicators, namely, the integration of traditional performance goals measured by traditional economic indicators (for example, profitability, GDP) and a set of new non-economic performance criteria that emphasize the satisfaction of needs of the customers, employees and all other stakeholders. The performance balanced scorecard approach is based on the efforts to build sustainable competitiveness taking into account multiple factors (Meyer, 2002). This new approach points to a set of new performance indicators and goals found in qualitative attributes such as culture, fulfillment, safety, health, natural resources preserving and development, mutual understanding, creativity, enhancing mutual trust, etc.Based on complexity, dependency and contingency theories, much effort is made to identify and select priorities by relevance criteria attributed to factors influencing the concrete technological strategies (Sanchez, 1996). The ultimate results of these efforts are: strengths better appreciated and further developed, while the weaknesses reduced and eliminated. At the same time, the orientation is at building capacities to grab opportunities and diminish threats in the environment. Sustainable management is a concept of strategic management oriented at the achievement of sustainable competitiveness. Sustainable competitiveness is based on appreciation of strategic goals emphasizing competitive co-evolution, networking and partnering be (Narayanan V, 2001), long-term perspective, synergies, satisfaction, and high quality of life standards. The emphasis on sustainable technology management is related to the role of technology and its position at the core of all the business operations, and with focus on primary operations delivering value in the form of products and services to the customers, but also in satisfying the goals of the society, economy, local community, while simultaneously developing profitable business results. Table 1 shows the results of the effort to relate the proclaimed principles of sustainable development of society and sustainable technology management. (Rainey, 2006).

The underlying principles of sustainable development basically integrate economic, social, industrial and environmental issues in decision and policy making, at all levels of the society. The identification of sustainability indicators means that actual criteria are defined and imposed by sustainable development in the four aforementioned societal dimensions which are setting the limits to the existing, traditional approach to technological management and development. Aims defined by sustainable development, even though setting the boundaries and limiting existing technological development practices, at the same time are adding new perspectives and insights in directing it towards search for new technological solutions and innovations based on new principles, for example, imitating natural cycles of material exchange, eco-substitution, dematerialization, recycling and over-all rationalization.

Sustainability indicators

The concept of sustainable development, as presented in the documents and results achieved at the sumit in Rio De Janeiro in 1992, has been accepted as worldwide

Table 1. Transforming the principles of sustainable development (SD) into the sustainable technology management and development (STMD) framework.

SD	STMD
Coexistence (the right to)	Strategic enterprise thinking, “cradle to grave“ approach, balanced objectives; strategies leading to followers approaching leaders; reducing technological gap; life-cycle thinking; value- chain approach; competency approach.
Recognize interdependence	Technological cooperation – vertical and horizontal relations; in-sourcing R&D; R&D consortia; technological fusion; competitive co-evolution.
Respect relationships	Value networks – business environment and natural world; Strategic technological alliances and networking-synergetic effects
Accept responsibility	Social responsibility – Integrity, Honesty, Enterprise Management; Leading technological change with environmentally sound options, ecologically conscious innovation - ECI, finding the right measure of technological change in relation to political, economic, social, technological and ecological factors - PESTE.
Create long-term value	Value creation Create operations based on technologies that offer products and services satisfying the needs of all the stakeholders.
Eliminate wastes	Continuous innovativeness and creativity; Life-cycle assessment–LCA; sustainable technological products and processes.
Rely on balanced solutions	Openness, transparency, balanced scorecard thinking; Strategic fit as balancing of strategic and operational technological goals
Design limitations	Risk mitigation; LCA; Risk assessment; Managing technological risks and threats at the same time accepting the chances and challenges; technological forecasting
Continuous improvement	Technological forecasting as the base for short-term/long-term plans and technological strategies

development strategy. It reaffirms the human legacy on healthy and productive life in accordance with nature and the integral approach giving equal importance to economic and social dimensions of development and environmental protection, as the basis of the environmental protection and all other policies at local, regional and global levels. Agenda 21, which had been adopted at that time as a strategic document, in the section related to the realization of sustainability objectives, recommends the development of specific indicators of sustainability, which would make the concept of sustainable development operational. Their main purpose is to guide, direct and manage the process of decision-making (United Nations Agenda 21, 1992).

This integration implies the involvement of virtually all traditional sectors of economic and governmental engagement and activities, such as: economic planning, agriculture, health, energy, water, natural resources, industry, education and the environment, involving the principal ministries of the governments. The assumption of integration is reflected in the dimensions of sustainable development, which contain social, economic, environmental and institutional indicators, and should be included in mechanisms for institutional integration (Figure 1). The developed set of indicators provides support to decision-makers for redirecting governmental actions towards sustainability. The indicators need to be understandable and also to integrate different dimensions of sustainability and technological challenge. Above all, they need to be, to the highest extent, derived from existing data, in order to provide easy data manipulation, fast and effective calculations.

The clearly determined set of indicators is the base for long-term monitoring of progress towards sustainable development at different levels - national, regional, etc. The creation of the set of indicators is under the strong influence of cultural characteristics of the region and the level of its industrial and technological development. In the process of applying the principals of sustainable development, each indicator can be updated or even replaced according to the changes of the infrastructure.

Interpretations of indicators are different, and it is perhaps more useful to identify the uses and desirable properties of indicators. The major functions of indicators, as emphasized by Tunstall (1992) and Gallopin (1997), are as follows:

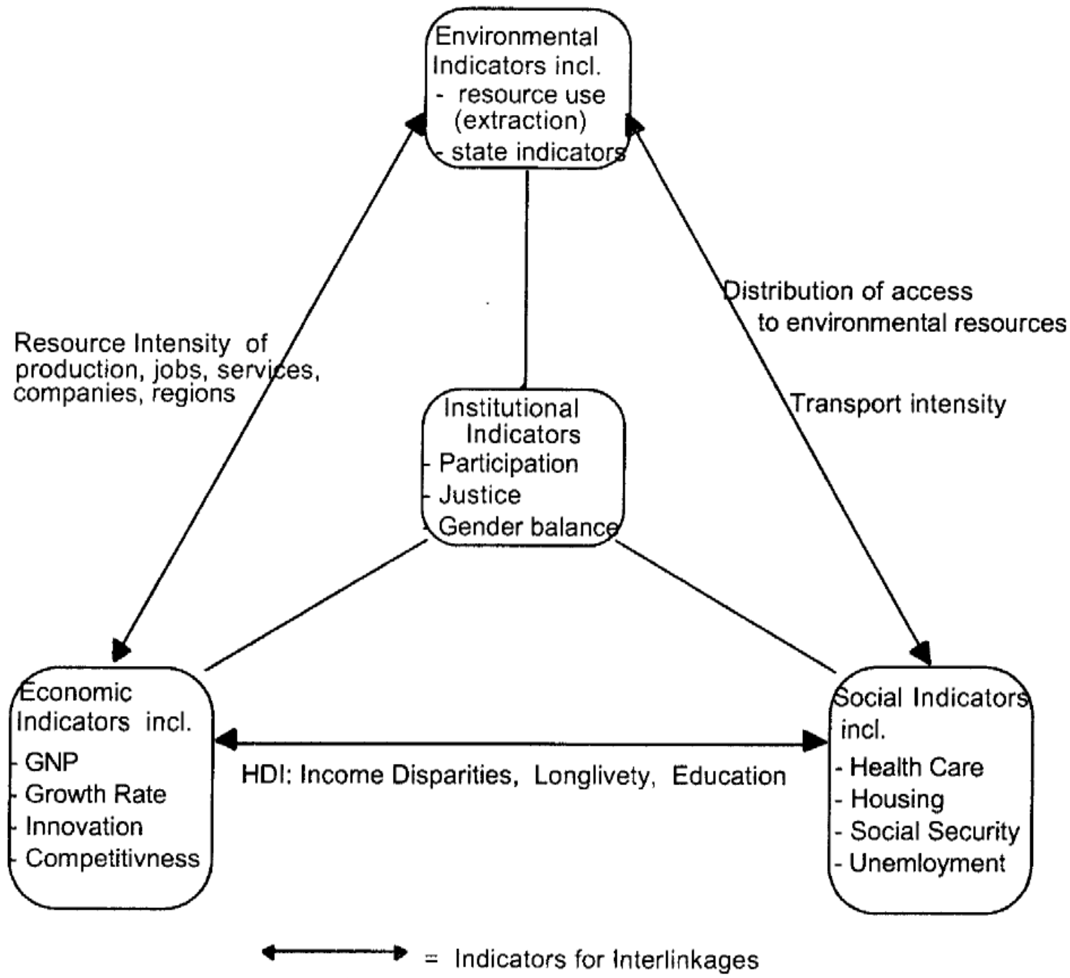

Figure 1. Sector and inter-linkage indicators (Spangeneberg, 1998).

i. to assess conditions and changes;
ii. to compare across space and situations;
iii. to assess conditions and trends in relation to goals and targets;
iv. to provide early warning information, and
v. to anticipate future conditions and trends.

The set of indicators, organized individually or in groups, aims at becoming a vital guidance in the process of collecting data. They are an important instrument for decision-makers, as they summarize crucial information from different sectors/sources. Also, they recommend logical grouping of information, by promoting their logical interpretation and integrations. In the process of collecting information, they help in discovering the needs for different type of data. In such manner, it is much easier to facilitate the reporting process, by structuring collected information in all aspects of sustainable development.

In order to define the set of indicators for the assessment of societal and technological development, relevant sectors or elements of the societal system are identified. They include the relevant elements that constitute society as well as the subsystems on which human society depends. Useful distinction of elements is presented thus

i. Individual development (civil liberties and human rights, equality, individual autonomy and self-determination, health, the right to work, social integration and participation, gender and class-specific role, material standard of living, qualification, specialization, adult education, family and life planning horizon, leisure and recreation, art, etc.);
ii. Society (population development, ethnic composition, income distribution and class structure, social groups and organizations, social security, medical care, old age provisions);
iii. Government (government and administration, public finances and taxes, political participation and democracy, conflict resolution (national, international), human rights policy, population and immigration policy, legal system, crime control, international assistance policy, technology

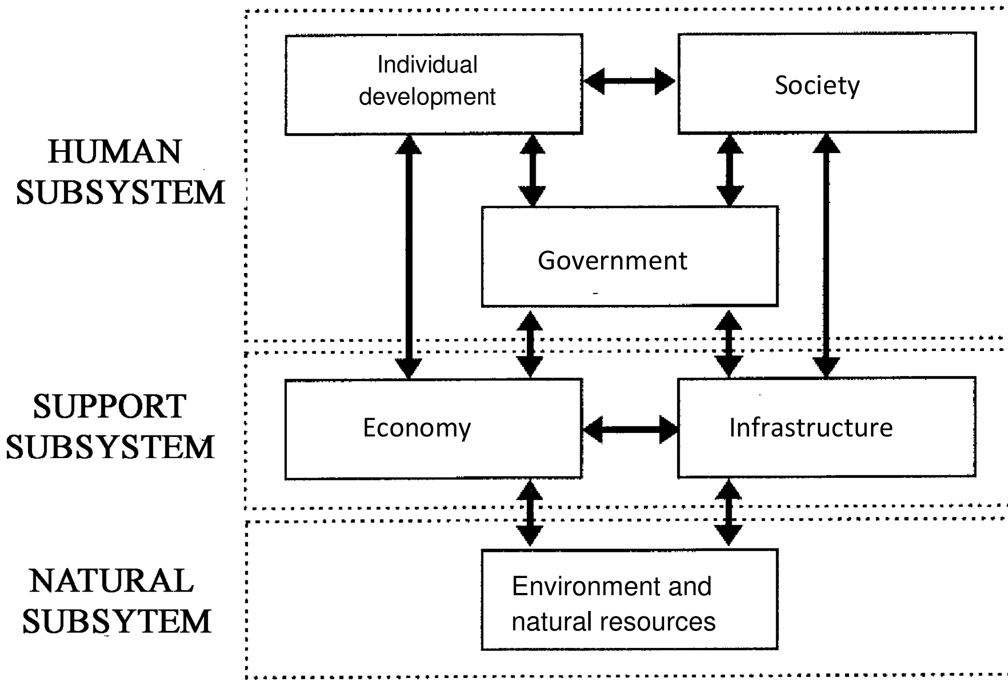

Figure 2. Elements and subsystems of the human society system (Bossel, 1999).

policy); Infrastructure (settlements and cities, transporttation and distribution, supply system (energy, water, food, goods, services), waste disposal, health services, communication and media, facilities for education and training, science, research and development);
iv. Economy (production and consumption, money, commerce and trade, labor and employment, income, market, interregional trade);
v. Resources and environment (natural environment, atmosphere and hydrosphere, natural resources, ecosystem, species, depletion of nonrenewable resources, regeneration of renewable resources, waste absorption, material recycling, pollution, degradation, carrying capacity (Bossel, 1999).

In order that the total system - the human system embedded in the natural system - is viable, each of these essential elements must be viable as well, that is, the viability of the total system depends on the proper functioning of the subsystems.

Although other classifications are possible, the presented identification of subsystems is not arbitrary. These subsystems are all essential parts of the "anthropologic sphere". The major relationships between the six elements are shown in Figure 2. Decomposing the system enables better insight into the relationships present in the system. Each constituent part can be observed from the aspect of its importance and potential contribution to the sustainability of the whole system (Bossel, 1999).

The number of indicators rises with the number of the identified subsystems that are included. To keep the number of the indicators at a reasonable level and by taking into consideration the basic organization of the society, the mentioned six elements are organized into three subsystems: natural subsystem, support subsystem and human subsystem.

The establishment and development of each of the mentioned subsystems is specifically reflected through technological development and initial resource usage. That is the reason why it is necessary, when the representative indicators are identified, to develop a conceptual understanding of the whole system. Complete and total understanding of the whole system is in the sphere of hypothetical and practically impossible; but one can search for missing information that will give the answers concerning essential processes and relationships between the components of the subsystems, and the subsystems themselves. In order that each subsystem is adequately represented and that all the aspects of its contribution to the sustainability of the societal system are covered, there is a need for a specific number of indicators to be developed.

Nevertheless, in the effort to identify specific, sector indicators, the components and subsystems that are the most important in that domain are to be determined in the first place (Bossel, 1999). Determining indicators based on the relations represented by the model (Figure 2) means that they are adapted to provide crucial guidance for decision-making in a variety of ways: they can translate knowledge in the natural, technical and social sciences domain into manageable units of information that can facilitate the decision-making process; they can help to measure and calibrate progress towards sustainable development goals; they can provide an early warning, sounding the alarm in time to prevent economic, social and environmental damage and limit the existing management of technological development; they are also important tools to communicate ideas, thoughts and values, as “we measure what we value, and value what we measure” (Shah, 2004).

Identification of sustainability indicators

Following the recommendations of the UN Agenda 21, the three subsystems are further developed and themes and sub-themes are derived. Later, in the stage of further distinction, the identification of indicators follows, as shown in Table 2. As presented, these indicators can provide actual guidance in forming the national list of indicators of sustainable development and cover issues generally common to all regions and countries of the world (United Nations Department of Economic and Social Affairs UNDES, 1999).

In the case of examining the management of some natural resource, the determined classification provides the base for the basic set of indicators to be identified, that will cover all crucial aspects (themes and sub-themes). These crucial areas will contain information about driving forces and mechanisms that lead to increased exploitation of natural resources. It should be emphasized at this point that the defining of sustainability indicators for some sectors has been limited by the amount of available data, where Statistical Yearbooks, World Bank Reports, Chamber of Commerce documents and World Health Organization surveys have been the main data sources. The proposed set of indicators directly point to the critical dimensions of the social system that have to be addressed and taken into consideration, while creating an instrument for the support of technology management and development in view of preserving natural resources.

Implementation of the objectives matrix model in measuring sustainability of technological development

In order to estimate the level of development, especially model (OMM) is developed. Originally, the matrix approach was developed with the aim of reviewing productivity of technology and its effectiveness and efficiency impacts on the prosperity of the company (Riggs, 1984). The characteristics of the original objectives matrix have been adapted to the needs of sustainable technology management objectives, and the new model built in this respect (OMM), has been developed and tested empirically in Serbia in the domain of air quality management. The factors that form the OMM are actually existing sustainability indicators that have already been selected, and for this purpose, chosen according to their highest contribution to the level of air quality. This especially refers to the indicators chosen from the natural subsystem. Altogether, there have been 24 indicators selected. Since the atmosphere and air quality have been at the focus of the natural subsystem, some themes represented in Table 2 have not been taken into consideration because they do not carry adequate information concerning air quality management (for example, housing, security, population, land, water, oceans, coasts and seas).Every indicator has been given weight coefficient in the matrix and the weights represent their estimated importance. In the presented case, since there are a large number of indicators, weighting coefficients are in the range from 2 to 6 (Table 3). The amount of the summed weighting coefficients has to be 100. Criteria for assigning certain weights to indicators are determined by the relevance of information that indicators provide, concerning in this case, the air quality management. In that sense, the highest importance has been given to the indicators that directly describe the state of air quality (like maximum emissions of SO_2 and NO_x) and their connections with technological, economical, political and scientific aspects.

Indicators with weight coefficient 6

The greatest importance (weight coefficient 6) have indicators that directly describe the air quality, so, there is no need for giving their detailed description. These are: maximum emissions of SO_2, maximum emissions of NO_x, emissions of kg CO_2 on annual level, per GDP and maximum soot concentration. Priority is given to these parameters also because of their global importance and direct linkage to atmospheric problems like global warming and ozone layer depletion. The rest of the indicators, that are evaluated with lower importance are linking above mentioned indicators with institutional, scientific, technological, economical and industrial aspects of the society.

Indicators with weight coefficient 5

The 6 parameters in Table 3, according to the importance in the framework of sustainable development of technology and natural resources, the objectives matrix level, have coefficient 5. From the group of the human podsystem themes, this would be indicators that imply on the endagered populition due to lower air quality (number of cancers of respiratory organs per 100 000 population) and the readiness of the community to invest in the improvement of environment (rate of budget investments in the environmental protection).

One of the ways to contribute to the decreasing of mentioned environmental problems (climate change, great number of deseas due to low air quality) is by reorienting the existing development towards sustainable- seraching

Table 2. Societal subsystems and derived indicators from themes and sub-themes.

Theme	Subtheme	Sustainability indicator
Human subsystem		
Equity	Poverty	Unemployment rate %
Education	Education level Literacy	Adult literacy rate
Health	Nutritional status	Mortality rate under 5 years old
	Mortality/diseases	Mortality rate (whole observed population)/rate of getting ill from specific diseases per 100 000 Population
	Drinking water	Population with Access to Safe drinking water
	Healthcare delivery	Health care expenditures as a % GDP-a
	Sanitation	Improved sanitation conditions on annual level (%)
Housing	Living conditions	Floor Area per Person
Security	Crime	Number of Recorded Crimes per 100,000 Population
Population	Population change	Population Growth Rate %
Institutional framework	National development strategy (role of government and institutions	Number of researchers per 1 000 000 Population
	National legal system/laws	Number of companies with adopted 14001 standards
	International cooperation	Implementation of Ratified Global Agreements
Institutional capacity	Decision-making participation	Number of communities that have adopted local Agenda 21
	Information access	Number of Internet Subscribers per 1000 Inhabitants
	Pollution prevention, disaster preparedness and response	Rate of budget investments in the environmental protection - %
Support subsystem		
Economic structure	Economic performance	Inflation rate
	Financial status	Amount of monetary supplies
	Trade	Import as a % GDP Export as a % GDP
Technological aspects	Material production and consumption	GDP (const. $ 2000)
	Competitiveness/innovativeness	Number of registered patents - annual level
	Energy use	Amount of produced energy from renewable resources in % Intensity of energy usage (koe per GDP)
	Waste Generation and Management	Amount of waste that can be recycled (%)
	Infrastructure and transport	Total road length in km Railway capacity, number of passengers per km
Natural subsystem		
Atmosphere	Climate change	Emissions of kg CO_2 on annual level, per GDP
	Ozone layer depletion	Maximum emissions of SO_2 Maximum emissions of NO_x
	Air quality	Maximum soot emissions

Table 2. Contd.

Land	Agriculture	Use of fertilizers
	Forests	Forest area as a percent of land area
	Urbanization	Area of urban formal and informal settlements
Oceans, seas and coasts	Coastal zone	Percent of total population living in coastal areas
	Fisheries	Annual catch by major species
Fresh water	Water quantity	Annual withdrawal of ground and surface water as a percent of total available water
	Water quality	Percentage of first class water
Biodiversity	Ecosystem	Number of national parks
	Species	Number of protected species from total

Table 3. Selected sustainability indicators and assigned importance level/weights.

Sustainability indicator	Importance level/weighting coefficient
Maximum emissions of SO_2	6
Maximum emissions of NO_x	6
Emissions of kg CO_2 on annual level, per GDP	6
Maximum soot concentration	6
Number of cancers of respiratory organs per 100 000 population	5
Rate of budget investments in the environmental protection	5
Number of researchers per 1 000 000 population	5
Number of implemented ratified global agreements in area of air quality management	5
Intensity of energy usage (koe per GDP)	5
Amount of produced energy from renewable resources u %	5
Number of companies with adopted 14001 standards	4
Import as a % GDP	4
Export as a % GDP	4
GDP (const. 2000$)	4
Inflation rate	4
Unemployment rate %	4
Amount of waste that can be recycled (%)	4
Number of registered patents on annual level	3
Total road length in km	3
Railway capacity, number of passengers per km	3
Health care expenditures as a % GDP	3
Number of communities that have adopted local Agenda 21	2
Number of internet subscribers per 1000 Inhabitants	2
Adult literacy rate	2

for new solutions. These solutions mostly come as a result of the scientific and innovative work. The level of that potentiol in Serbia can be found in values of the indicator number of researchers per 1 000 000 population. The main matrix (Table 4) in the OMM has thus been created. Other direction through which we can influence the solving of environmental problems is the tendency of fulfilling international obligations and regulations – in this case, the implementing ratified global agreements in area of air quality management. In that way, we indirectly influence on the domestic legal framework to get in compliance with international regulatives and normatives. Indicator: number of implemented ratified global agreements gives that information and shows

Table 4. The objectives matrix for measurement of technological and natural resources development, based on example of air quality management.

Sustainability indicator	Scale of grades					Real value of indicator	Estimated grade	Weight f.	Value
	1	2	3	4	5				
Unemployment rate %	22	18	14	10	6	28	1	4	4
Adult Literacy rate %	92	94	96	98	100	98	4	2	8
Number of cancers of respiratory organs per 100 000 population	60	50	40	30	20	39.4	3	5	15
Health care expenditures as a % GDP	6	7	8	9	10	8	3	3	9
Number of researchers per 1 000 000 population	1000	2000	3000	4000	5000	1330	1	5	5
Number of implemented ratified global agreements in area of air quality management	4	8	12	16	20	9	2	5	10
Number of companies with adopted 14001 standards	50	150	250	350	450	27	1	4	4
Number of communities that have adopted local Agenda 21	30	60	90	120	150	25	1	2	2
Number of Internet Subscribers per 1000 Inhabitants	50	150	250	350	450	200	2	2	4
Rate of budget investments in the environmental protection (%)	0.2	1	1.8	2.6	3.2	0.3	1	5	5
Inflation rate (%)	23	18	13	7	2	16	2	4	8
Import per GDP (%)	47	45	43	41	39	45	2	4	8
Export per GDP (%)	20	25	35	40	45	24	1	4	4
GDP (const. $ 2000)	1000	1600	2200	2800	3400	1272	1	4	4
Number of registered patents on annual level	500	1200	1900	2600	3300	507	1	3	3
Amount of produced energy from renewable resources in %	5	10	15	20	25	6.9	1	5	5
Intensity of energy usage (koe per GDP)	0.9	0.8	0.7	0.6	0.5	0.8	2	5	10
Amount of waste that can be recycled (%)	30	40	50	60	70	40	2	4	8
Total road length in km	20 000	30 000	40 000	50 000	60 000	36 500	2	3	6
Railway capacity, number of passengers per km	500 000	2 500 000	3 500 000	4 500 000	5 500 000	1 023 000	1	3	3
Maximum emissions of SO_2	180	160	140	120	100	243	1	6	6
Maximum emissions of NO_x	150	130	110	90	70	130	2	6	12
Emissions of kg CO_2 on annual level, per GDP	4.5	3.5	2.5	1.5	0.5	3.1	2	6	12
Maximum soot concentration	100	85	70	55	40	90	1	6	6
Resulted value									161

the capability of state capacities to follow the international requirements.

In Serbia, energy sector is the one that, with its emisions in great deal, contributes to poor air quality and the part of support subsystem that greatly impacts the natural subsystem. Monitoring the intensity of energy usage (koe per GDP) is a direct indicator of energy (un)efficiency and has weight coefficient 5. If we look in more detail

Table 5. Real values of indicators with assigned grades.

Sustainability indicator	Real value of the indicator	Assigned grade to the indicator in relation to the its real value in the matrix
Unemployment rate	28	1
Number of researchers per 1 000 000 population	1330	1
Number of companies with adopted 14001 standards	27	1
Number of communities that have adopted local Agenda 21	25	1
% of budget investments in the environmental protection	0.3	1
Export as a % GDP	24	1
GDP (const. 2000$)	1272	1
Number of registered patents on annual level	507	1
Amount of produced energy from renewable resources in %	6.9	1
Railway capacity, number of passengers per km	1 023 000	1
Maximum emissions of SO_2	243	1
Maximum soot concentration	90	1
Number of implemented ratified global agreements in area of air quality management	9	2
Number of internet subscribers per 1000 inhabitants	200	2
Inflation rate	16	2
Import as a % GDP	45	2
Intensity of energy usage (koe per GDP)	0.8	2
Amount of waste that can be recycled (%)	40	2
Total road length in km	36 500	2
Maximum emissions of NO_x	130	2
Emissions of kg CO_2 on annual level, per GDP	3.1	2
Number of cancers of respiratory organs per 100 000 population	39.4	3
Health care expenditures as a % GDP-a	8	3
Adult literacy rate	98	4

(Table 5) at the grades and concrete values of indicators, few critical areas are exposed, that are mostly to blame for the decreasing of the air quality in Serbia. How one of the principles of sustainable development lowers the usage of the fossil fuels and how it takes into account alternative resources of energy, is an indicator of the amount of produced energy from renewable resources (u%) shown by Serbia concerning this matter and it holds a weight coefficient of 5.

Indicators with weight coefficinet 4

Next group of seven indicators carries weight coefficient 4. These indicators give information that are not so closely related to the air quality, but correspond to health, environmental protection, and economical state that influence that natural subsystem.

Adopting standards and regulatives, but at microlevel where a starting point can be a technological unit or a company is an actual basis of management system transformations at macrolevel. Monitoring the number of companies with adopted 14001 standards can show the rate of the developed conditions for sustainable development. Since greater number of companies adopts this management model, the society is closer to sustainable development goals.

Economical parameters, like import as %GDP, export as %GDP and GDP (const. $ 2000), directly describe the industrial position and states the economical status. In addition to this indicator, we can also derive the indicator inflation rate that gives a picture of the states' macro-economical stability.

Tightly linked parameter from the human subsystem with economical parameters is unemployment rate since it indicates the level of poverty which describes the population capabiliteis to contribute to environmental protection.

Human subsystem in its activities generates great amounts of waste, that are mostly stored and eliminated in natural subsystem. In attempts to protect it, in application are recycling processes and the usage of secondary raw materials. The amount of waste that can be recycled (%) is an important indicator of how much the society has advanced in that field with technology improvements.

Indicators with weight coefficient 3

In this category has been identified 4 parameters. As an additional indicator of technological aspects in the area of support subsystem is number of registered patents on annual level. Competitiveness and innovativeness have important role in development of clean technologies, especially the ones that will contribute to lowering of emissions and imissions. Mentioned parameter indicates general state potential in area of innovations.

In the group of support subsystem indicators, which imply on the infrastructural development are total road length in km and railway capacity, number of passengers per km. Higher level of infrastructural development influences on the more efficient and secure transport, gives the opportunities for savings, and is one of the bridges that human subsystem "communicates" with naturally.

In this group of indicators also belongs the one that indicates health care expenditures as a percentage GDP-a and gives general information on the populations capabilities to provide itself adequate health care.

Indicators with weight coefficient 2

This category of indicators carry level of importance 2. Indicators in this group are evaluated like that, bacause the information they are giving is not directly relevant to atmospheric change, but rather shows general populations motivation, access to information and willingness to participate in decision making. The first indicator in this group is number of communities that have adopted local Agenda 21 and relates to application of local ecological action plans.

How good is access to information, in the era when information technology dominates, number of internet subscribers per 1000 inhabitants can reveal that. The last indicator: adult literacy rate, gives clearer picture of educational level and individual developemnt.

In the OMM, grades are given from 1 to 5 in relation to the obtained empirical values of observed indicators for a certain period. As the highest obtainable values, carrying the grade 5, used further on for defining the scale of grades, relates to the data represented for the indicators in Republic of Denmark, since this is one of the European countries that is mostly advanced in terms of sustainable development and innovations, and this data is publicly available. For data resources, the following internet databases from: World Bank, Denmark Statistics, Denmark environmental protection agency, Serbian Statistics Institute and World Health Organization, have been used.

For some indicators, such as the highest values graded 5, the maximum allowed values regulated by domestic laws were used, while for the lowest limits graded 1, the worst values that could be allowed were introduced.

The main matrix (Table 4) in the OMM has thus been created, where grade 5 refers to the level of an indicator achieved by a highly developed European country, and should represent an optimistic goal towards which Serbia needs to strive for in the future. It is determined and limited to a certain time period, which depends on the nature of indicator.

Considering numerical values, grade 3 is allocated to average real values of the indicator, which means that by multiplying with 100m (sum of weights), the overall average value calculated at a certain point of time is 300. The actual overall calculated value of the matrix based on the real, empirical data for individual indicators, should therefore be compared in order that significant conclusions be drawn. The comparisons can be made in the following manner:

a) Comparing the real obtained overall value with the average value of 300 shows that all the values above are to be considered acceptable and in the range of positive results, while all the values below the average should be considered alarming and should call for high priority actions;
b) Comparisons should be made by periodically testing the model with real values at different points in time for monitoring progress in the domain of sustainability;
c) Comparisons are to be made with benchmark countries, as in the case presented, where Denmark has set the benchmark for the 500 grade value which is translated in real value for certain indicators that are compared and the ones who are most below the aimed value are considered as critical.

The overall value of the matrix, in the case of Serbia, has been calculated and amounts to 161. It represents 53.7%

below of the average value of 300. The results by using the OMM show the overall evaluated status of Serbia in the field of sustainable technological development from the point of view of air quality management. If we look in more detail (Table 5) at the grades and concrete values of indicators, few critical areas are exposed, that are mostly to blame for the decreasing of the air quality in Serbia.

The grades are very low with average display from 1 to 2. From a total of 24 indicators:

i. 12 indicators hold grade 1;
ii. 9 indicators hold grade 2;
iii. 2 indicatros hold grade 3; and
iv. 1 indicator hold grade 4.

When we look at the current structure of the indicators according to their grades, it follows that practical reforms are needed in great number in social and technological aspects. However, the most critical points that have been distinguished are in relation to increased poverty, lack of clear direction of the strategy of scientific and technological development, poor institutional organization and weak economic structure. In the frame of technological aspects are highlighted problems of poor energy efficiency, which is associated with bad policies that are implemented in the companies, and insufficient investments in the infrastructure improvements.

The over-limitations of allowed values of emissions are found to be the critical points. The problems of bad and low energy efficiency have been detected as the critical factors of the low result in air quality management features in Serbia. This result is connected to the problems of establishing optimal investment policies and problems in the sphere of scientific and technological development strategies. The data used for developing the OMM are for the period from 2001 to 2003.

It should be emphasized that the selection of derived indicators in this paper has been limited partly with the availability of required data. Presentation and analysis of indicators for air quality management in this way had the purpose to show how through the knowledge of the relevant parameters we can adequately manage the technology development and natural resources. Some identified indicators open other sectoral policies as well - not only the area of air quality management. As such, they carry within the information concerning great number of industrial processes. They can be a good introduction to the establishment (of the system) of national sustainable development indicators in line with the capacities and needs of Serbia, while respecting the requirements of international comparability (standardized concepts, definitions and classifications).

By implementing the model and testing it empirically for the case of Serbia, we actually quantified and graded the sustainability of Serbia, for the mentioned period. The overall value of 161 obtained in the calculations of the matrix is far below the average value of 300 and shows that Serbia has to initialize quick responsive measures and make a high priority action plan supported by great efforts in numerous social, economic and technological domains, in order to obtain progress towards sustainability.

Conclusion

The results obtained in developing OMM for sustainable technological management and development. The empirical analysis for the case of Serbia has shown a potential significant contribution to theory and practice of managing sustainability at different levels more widely. This paper points to the potentials of the OMM and its robustness in terms of processing data related to different indicators referring to concrete situations and aims of the analysis.

Practically, it has been shown that OMM is a valuable tool applicable to different countries, at the level of national economies and regions in their effort to manage sustainability. By forming a representative list of indicators, one can easily monitor processes and provide necessary measurements in order to progress in relation to sustainability. Organizing the indicators into OMM means going a step ahead in the level of processing relevant sustainability indicators for management purposes.

The analysis has been developed at two levels: first, the creation of a representative list of indicators for air quality management, and second, establishing the objectives matrix model using comparable data of a developed country against which grades are created and the concrete position of Serbia. Originally developed for analyzing the productivity of technology at company level, the OMM has shown its potentials for implementation at macro-management levels as well which point to its flexibility verified in practice by sustainability results of air quality management obtained in the analyzed case.

REFERENCES

Barney JB (2004). Firm resources and sustained competitive advantage. J. Manage., 17 (1): 99-120.

Bossel H (1999). A report to the Balaton Group: Indicators for Sustainable Development: Theory, Method, Applications.

Gallopin G (1997). Indicators and their use: information for decision making, in Moldan B. and Billharz S. Sustainability Indicators. Report on the project on Indicators of Sustainable Development. John Wiley & Sons.

Meyer M (2002). Rethinking Performance Management, Cambridge University Press.

Narayanan V (2001). Managing Technology and Innovation for Competitive Advantage. Prentice Hall.

Rainey D (2006). Sustainable Business Development. Cambridge University Press. Cambridge.

Riggs JL (1984). The Objectives Matrix for Productivity Measurement, Oper. Manage. Rev., 2 (4): 3-14

Sanchez R et al. ed (1996). Dynamics of Competence Based Competition. Pergamon Press.

Shah R (2004). CSD Indicators of sustainable development – recent developments and activities. ASI workshop. Pargue, Czech Republick.

Spangenberg J, Bonniot O (1998). Sustainability Indicators – A Compass on the road towards sustainability. Paper No. 81. Wuppertal Institute, Germany.

Spangenberg J, Mesicek R, Metzner A, Luks F (2002). Sustainability Indicators for the Knowledge based society. Futura.

Tunstall D (1992). Developing environmental indicators: definitions framework and issues. Background materials for the world resources institute workshop on global environmental indicators. Washington DC.

United Nations Department of Economic and Social Affairs UNDES (1999). Theme Framework and Indicators of Sustainability. PriceWaterhouseCoopers for Division for Sustainable Development.

United Nations (1992). Agenda 21: Programme of Action for Sustainable Development, United Nations Conference on Environment and Development. Rio de Janeiro, Brazil, Chapters, 3, 4, 24, 25, and 26.