International Journal of Technology (2015) 5: 886-893
ISSN 2086-9614

POLICY ANALYSIS OF THE JAKARTA CARBON MITIGATION PLAN USING SYSTEM DYNAMICS TO SUPPORT DECISION MAKING IN URBAN DEVELOPMENT – OPTIONS FOR POLICYMAKERS

Akhmad Hidayatno[1*], Irvanu Rahman[1], Ricki Muliadi[1]

[1] *System Engineering, Modeling, and Simulation Laboratory, Department of Industrial Engineering, Faculty of Engineering, Universitas Indonesia, Kampus Baru UI Depok, Depok 16424, Indonesia*

(Received: June 2015 / Revised: September 2015 / Accepted: September 2015)

ABSTRACT

Cities are facing ever greater challenges regarding climate change. Urban governments and policymakers have taken such challenges into account when maintaining urban development momentum. Although the city government of Jakarta has implemented several initiatives to reduce emissions, assessments of the impact of these strategies on the sustainability of the urban system remain limited. This paper investigates the evaluation of two mitigation scenarios for reducing Jakarta's greenhouse gases that differ in the authority level of the local government, using a policy analysis approach. The method emphasizes the use of the system dynamics model to gain insights into each option. The results reveal that the city's development goals would be best achieved through joint partnership with the national government. Such cooperation would have a more significant effect on economic, social, and environmental sustainability than would be in the case in other scenarios.

Keywords: Climate change mitigation; Greenhouse gases; Policy analysis; System dynamics; Urban sustainability

1. INTRODUCTION

Scientists have confirmed that climate change significantly affects urban areas. More than 600 world cities are now estimated to have suffered increasingly adverse impacts on their economies, populations, and ecosystems, due to ever more extreme climate events (Lankao, 2008). The IPCC assessment report found that these hazards are mostly driven by increasing emissions in cities, due to significant energy consumption by households, industries, and infrastructures (IPCC, 2014). In addition, the effect of greenhouse gas emissions on people's health, equity, and economic productivity is evident, as shown by Kjellstrom et al. (2007) and Cole and Neumayer (2006). All of these risks are emerging as sustainability challenges that must be addressed by urban governments; therefore, climate mitigation and adaptation efforts are intrinsic aspects of long-term city planning.

As a global urban centers, Jakarta's economy has been affected by global climate changes. A previous study by the present authors showed that although Jakarta is set to enjoy significant economic progress, growth will gradually slow down by 2030 as a result of emissions' impact on labor productivity (Hidayatno et al., 2014). To tackle these problems, the Government of Jakarta has responded with a Carbon Mitigation Policy at the city level *(RAD-GRK 2030)* as a guide for the city's stakeholders regarding reduction of emissions. However, systems are still

* Corresponding author's email: akhmad@eng.ui.ac.id, Tel. +62-21-78888805, Fax. +62-21-78885656
Permalink/DOI: http://dx.doi.org/10.14716/ijtech.v6i5.1926

limited. Therefore, this research aims to evaluate the impact of the Jakarta RAD-GRK strategic plan on the triple bottom line of urban development, using the combined methods of system dynamics and policy analysis. The policy analysis framework will enable decision-makers to map conflicting goals and design robust policy alternatives, by emphasizing the use of the system dynamics model in incorporating individual system components. We will then comprehensively analyze the interactions of these elements and study the long-term implications for various policies (Guan et. al., 2011). The assessment will mainly be centered on how urban development targets can be achieved in conjunction with emission reduction efforts

2. METHODOLOGY

City structures are unique and complex systems. Dynamic interactions among variables associated with the economy, urbanization, and climate change lead to convoluted relationships in an organized complexity (Feng et al., 2012). As problems arise, governments are faced with uncertainties in how to choose intervention alternatives that may produce further manifold impacts.

Over the past few decades, scientists have developed a systems-based approach for addressing policy issues and measuring their impact in terms of trade-offs; this is known as policy analysis. The method originates from the operation research field, which has been widely used for optimizing problems with a single objective function; it evolved through system analysis to become a policy analysis, by highlighting the combination of analytical concepts and computer models (Walker, 2000).

The use of computer models is of prime importance in policy analysis methodology. Bankes (1993) emphasizes that models used in policy studies are used to provide relevancies of problems and to search for insights, rather than to make specific number-based predictions. In their early development, Walker (1978) established basic steps in analyzing policy alternatives, and emphasized the use of system dynamics (SD) as a tool for evaluating each scenario. The SD model is not just used to uncover the complexity and dynamic behavior of systems (Forrester, 1994; Sterman, 2000), it also enables policymakers to find leverage points to alleviate relevant problems (Barlas, 2002).

This paper will discuss how the Jakarta Carbon Mitigation Policy could reduce the impact of climate change on cities' development, using the policy analysis approach as the primary model case. The method is conducted in six major stages, as shown in Figure 1. In the first two steps, we will try to address the main concerns of decision-makers in maintaining Jakarta's sustainability of development. In relation to this sustainable policy, the Government of Jakarta has set the city's development goals: *economic development*, *green space expansion*, and *emission reduction*.

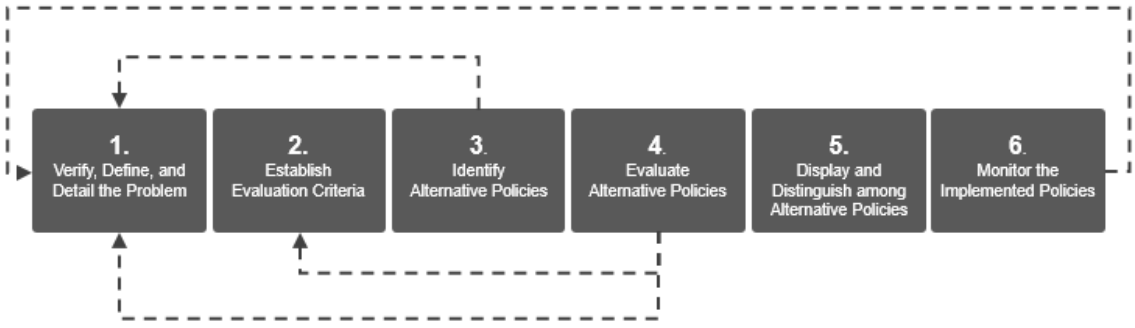

Figure 1 Six basic steps in policy analysis

The development targets, as presented in Table 1, have posed a dilemma for governments in their decision-making processes: *"Is it possible to reduce greenhouse gas emissions and expand green spaces without slowing operation and economic growth? If so, at what cost?"* These premises will serve as evaluation criteria and the main indicators for decision-makers in evaluating the Jakarta carbon mitigation policy options.

Table 1 The three development targets as policy evaluation criteria

Main Concerns	Indicators	Targets
1. Economic Development	Economic (GDP) Growth	7–8% Annually
2. Green Space Expansion	Green Space Proportion	30% from Total Land
3. Emission Reduction	Greenhouse Gas Emissions	30% from Business as Usual

Two alternatives have been identified and differentiated by the Jakarta government's levels of authority. The first alternative, the Middle-Control Scenario, assumes that mitigation is carried out by the government with national support and the help of donors from foreign countries. The effort comprises two areas of mitigation: energy consumption and land use activities. The second option, the High-Control Scenario, is more independent and covers a broader range of aspects compared to the first; it looks at the additional effort of waste reduction in two forms, liquid and solid wastes. A summary of both alternatives is given in Table 2.

Table 2 List of Jakarta carbon mitigation policy scenarios

Sector of Mitigation	Subsectors	Middle-Control (MCS)	High-Control (HCS)
Energy Consumption	Services	✓	✓
	Industries	✓	×
	Households	✓	×
	Transportations	✓	✓
Land Use, Land Use Change, and Forestry	Forest	×	✓
	Green Space	✓	✓
Waste	Solid	×	✓
	Liquid	×	✓

Both scenarios were evaluated using the Jakarta Sustainable Urban Model, which was first developed through the use of system dynamics in our previous studies (Hidayatno et al., 2014). The basic relationships of the model were generated from the T21 Papua Model (Millennium Institute, 2000) and the Indonesia Sustainability Model (Hidayatno et al., 2011), which cover production sector of agriculture, service, and industry; population; labor force; life expectancy; education; land allocation; water supply; and air quality, including several key relationships between air pollution impacts on health, based on works by Ostro (1994), Hansen and Selte (1997), and Madsen and Willcox (2006). These relationships were conceptualized using causal-loop and system diagram approaches, shown in Figure 2, to depict connections in terms of how government policies could be transmitted into the system, and to quantify the impacts through a set of city-indicators for decision-making. The use of the system diagram will enable

policymakers to visualize the structure of the problem by incorporating steering factors, externalities, and desired parameters (Lei et al., 2011).

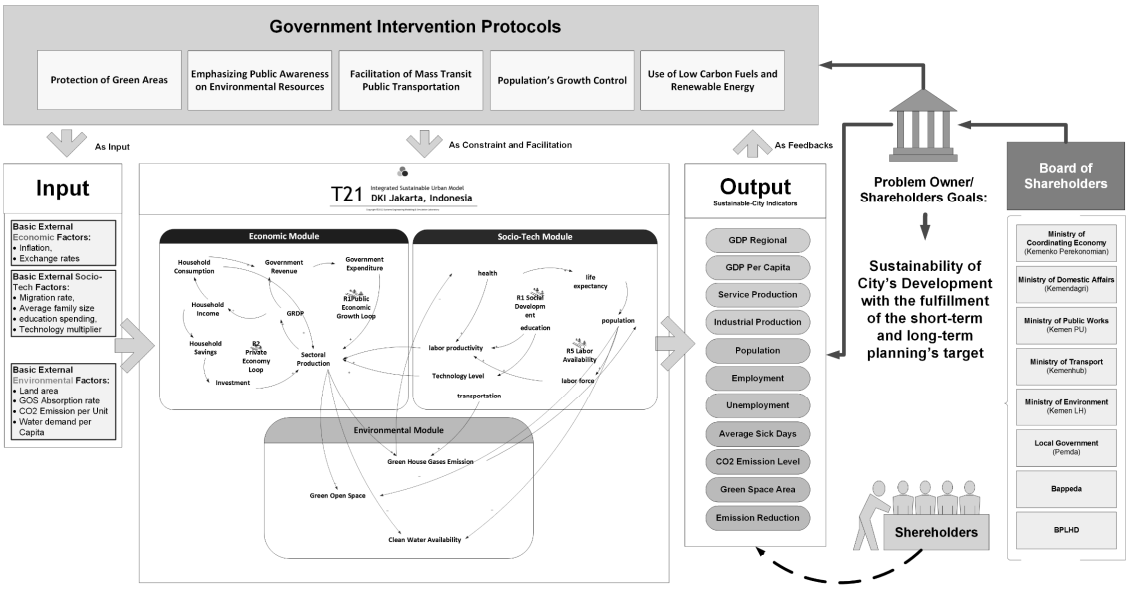

Figure 2 Model conceptualization of Jakarta sustainable development model

The conceptual model was categorized into three aspects of sustainability: economic, socio-tech, and environmental modules. The Jakarta Carbon Mitigation Policy will intervene in the system through sectoral productions in the economic module, through the population and transportations in the socio-tech module, and through land allocation in the environmental module. All emissions from these sectors were aggregated in the air quality and emissions submodule. Rising emissions will increase the risk of death for the population, affect health equity, and induce productivity loss in the economy. All captured variables from the model conceptualization were then transformed into a stock and flow diagram, as shown in Figure 3.

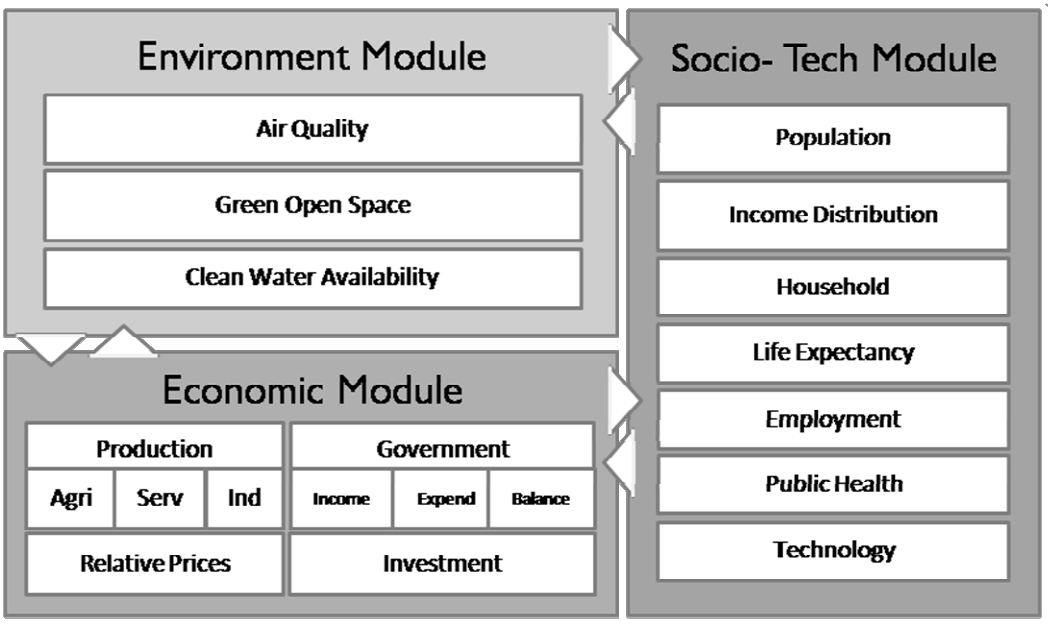

Figure 3 Modules and submodules of Jakarta's sustainable development model

3. RESULTS AND DISCUSSION

Our research ran the model in three conditions, with business as usual as the baseline condition, along with the two scenarios previously discussed. The research displayed overall indicators and goal attainments for each alternative, as summarized in Tables 3 and 4.

Table 3 Overall indicators of Jakarta's sustainable development model

Jakarta Sustainable Indicators		Business As Usual		MC Scenario	HC Scenario
		2006	2030	2030	2030
GDP Regional	USD	35.051.288.806	79.510.925.578	79.367.704.915	79.433.264.917
Service Production	USD	29.739.794.356	70.207.883.979	70.075.249.921	70.136.769.210
Per Capita Income	USD/Person	3.819	4.685	4.713	4.906
Population	Person	8.961.680	12.967.223	13.108.333	13.028.276
Employment	Person	3.531.799	5.206.496	5.206.483	5.206.481
Unemployment Rate	%	12 %	10 %	11 %	11 %
Per Capita Income	USD/Person	3.819	4.685	4.685	4.685
Number of Sick Days	Days	21	36	36	36
GHG Emission	Ton	35.254.950	103.230.582	82.000.569	98.799.846
Green Space (GOS)	Hectare	1.007,49	8.746,38	20.082,69	12.741,48
GHG Absorbed by GOS	Ton	573.332	4.977.304	11.428.456	7.250.796

Table 4 Goal attainments of Jakarta carbon mitigation policy scenarios

Main Concerns	Target	BAU Scenario	MC Scenario	HC Scenario
		2030	2030	2030
Annual Economic Growth (avg.)	7.5%	3.5%	3.5%	3.5%
Emission Reduction from BAU	30%	-	20.6%	4.3%
Green Space Proportion	30%	13.2%	30.4%	19.3%

In the economic aspect, the High-Control Scenario showed the most significant progress among the alternatives, as indicated by the escalation levels of per capita income and the Gross Domestic Regional Product, which is mainly driven by service production. Nevertheless, both the Middle-Control and High-Control scenarios failed to achieve the annual economic growth target. The model revealed the same pattern of growth behavior for all policy options, which indicates that Jakarta faces eventual economic slowdown, with or without mitigation efforts (Figure 4).

In terms of emissions targets, the the Middle-Control scenario performed best, with a 20.6% total reduction from the Business as Usual scenario, whereas the High-Control scenario resulted in only a 4.3% reduction. The discrepancy of targets among the alternatives, as presented in Figure 5, was caused by the effort scope distinguished by the authority levels of Jakarta's government. The joint effort between local and national governments also yielded a 100% accomplishment of green space development goals, and the highest capacity in reducing emissions, as shown by the 'Green Space' and 'GHG Absorbed by GOS' parameters.

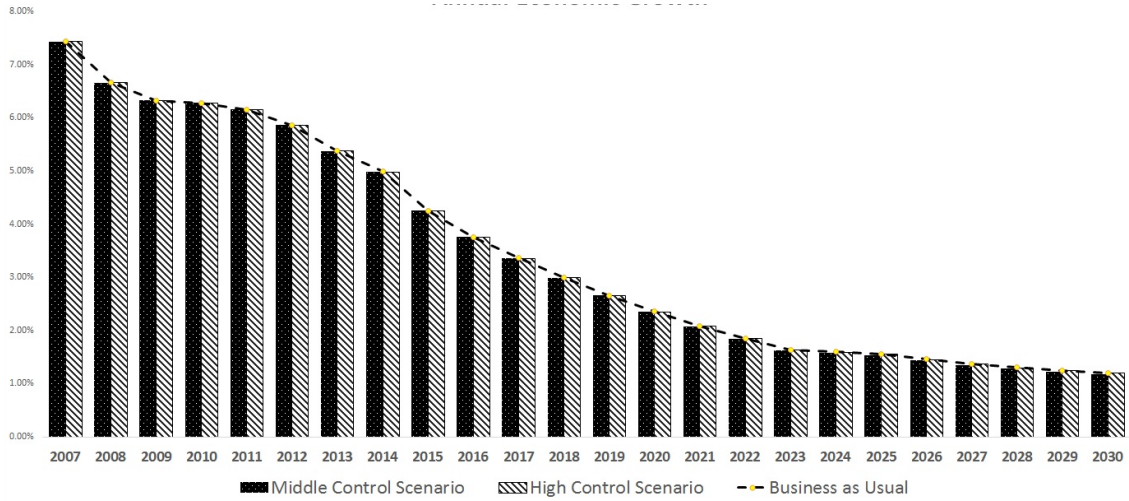

Figure 4 Behavior-over-time of economic growth for each alternative

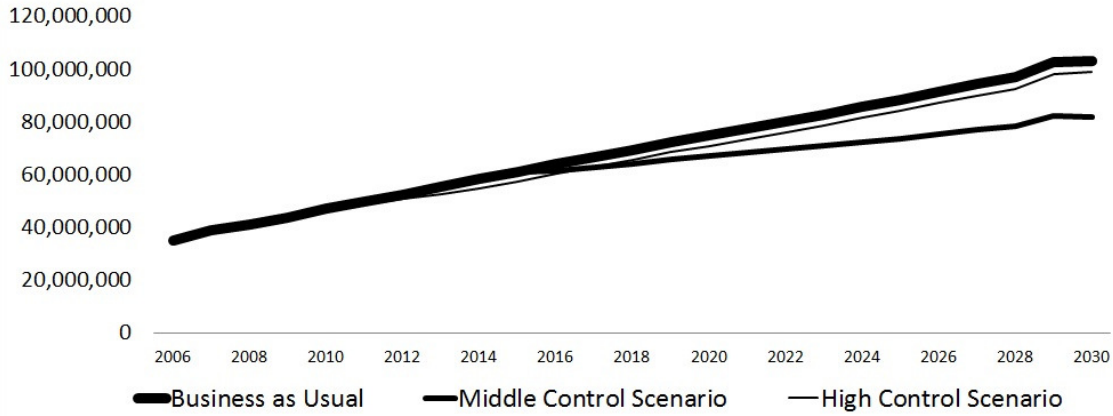

Figure 5 Behavior-over-time of greenhouses gases emissions

Based on the results, the analysis shows that the Middle-Control scenario yields the best goal attainment among the policy alternatives. Cooperation with national government is the most plausible option for the Government of Jakarta in reducing climate change impacts on the city's development. In addition, Jakarta's government should not only put more effort into emissions reduction, but should also stimulate the city's development through investment, partnership with both public and private schemes, and provision of affordable public transportat that promotes the use of low-carbon energies.

4. CONCLUSION

The present study aimed to reveals the impact of the Jakarta Carbon Mitigation Policy on the triple bottom line of city sustainability aspects, using a policy analysis approach. This paper also emphasized the use of the system dynamics model in assessing government climate strategies, and gave plausible options for policymakers in order to support better decision-making.

In the policy evaluation process, the local government has set the long-term development goals that have been addressed in this study as evaluation criteria for each scenario. The simulation displayed counter-intuitive results for all scenarios in terms of the behavior of economic indicators. Cooperation between local and national governments will result in the best scheme

for reducing climate change's impact on Jakarta's development. On top of these results, the use of the system dynamics model for policy analysis has shed new light on the Indonesian city-planning process. The model was able to generate a set of sustainable-city indicators that present the benefits and costs of development policies, in order to support robust decision-making.

6. REFERENCES

Bankes, S.C., 1993. Exploratory Modeling and the Use of Simulation for Policy Analysis. *RAND Note*

Barlas, Y., 2002. System Dynamics: Systemic Feedback Modeling for Policy Analysis. *Encyclopedia of Life Support System*, Boğaziçi University, pp. 1131–1175

Bruijn, H.D., Herder, P.M., 2009. System and Actor Perspectives on Sociotechnical Systems. *IEEE Transactions on Systems, Man, and Cybernetics—Part A: Systems and Humans*, Volume 39, pp. 981–992

Cole, M.A., Neumayer, E., 2006. The Impact of Poor Health on Total Factor Productivity. Routledge: Taylor & Francis, *Journal of Development Studies*, Volume 42(6), pp. 918–938

Feng, Y., Chen, S., Zhang, L., 2012. System Dynamics Modeling for Urban Energy Consumption and CO_2 Emissions: A Case Study of Beijing, China. *Ecological Modeling*, Volume 252, pp. 44–52

Forrester, J.W., 1994. System Dynamics, Systems Thinking, and Soft OR. *System Dynamics Review*, Volume 10(2-3), pp. 245–256

Guan, D., Gao, W., Su, W., Li, H., Hokao, K., 2011. Modeling and Dynamic Assessment of Urban Economy–resource–environment System with a Coupled System Dynamics–geographic Information System Model. *Elsevier - Ecological Indicators*, Volume 1, pp. 1333–1344

Hansen, A.C., Selte, H.K., 1997. Air Pollution and Sick Leave – Is there a Connection? A Case Study using Air Pollution Data from Oslo. *Statistics Norway*, pp. 3–18

Hidayatno, A., Rahman, I., Muliadi, R., 2014. Understanding Dynamics of Green House Gases Impacts on Jakarta's Urban Development using Model-based Policy Simulator to Support Policy Making. *International Conference on Industrial Engineering and Operations Management, Bali: IEOM Society*, pp. 1209–1214

Hidayatno, A., Sutrisno, A., Zagloel, Y.M., Purwanto, W., 2011. System Dynamics Sustanability Model of Palm-oil-based Biodiesel Production Chain in Indonesia. *International Journal of Engineering and Technology*, Volume 11(3), pp. 1–6

IPCC, 2014. Climate Change 2014: *Synthesis Report - Summary for Policy Makers*. Intergovernmental Panel on Climate Change

Kjellstrom, T., Friel, S., Dixon, J., Corvalan, C., Rehfuess, E., Campbell-Lendrum, D., et al., 2007. Urban Environmental Health Hazards and Health Equity. *Journal of Urban Health: Bulletin of the New York Academy of Medicine*, Volume 84(1), pp. 86–97

Lankao, P.R., 2008. Urban Areas and Climate Change: Review of Current Issues and Trends, Issues Paper for the 2011 *Global Report on Human Settlements*

Lei, T.V., Eserink, B., Thissen, W., Bekebrede, G., 2011. How to use a System Diagram to Analyze and Structure Complex Problems for Policy Issue Papers. *Journal of Operation Research Society,* Volume 62(7), pp. 1391–1402

Madsen, T., Willcox, N., 2006. Air Pollution and Public Health in Pennsylvania. *Penn Environment Research and Policy Center*, Philadelphia

Millennium Institute, 2000. *Threshold 21 (T21) Overview*. USA: Millennium Institute

Ostro, B., 1994. Estimating the Health Impact of Air Pollution: Methodology and an Application to Jakarta. *Policy Research Working Paper*, Public Economic Division, Policy Research Department - The World Bank, Washington, DC

Patton, C.V., Sawicki, D.S., 1993. *Basic Methods of Policy Analysis and Planning*. New Jersey: Prentice Hall

Solomon, S., Qin, D., Manning, M., Che, Z.M.M., Averyt, K., Miller, H., 2007. Climate Change - The Physical Science Basis. *In:* Contribution of the Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, Cambridge University Press, Cambridge

Sterman, J.D., 2000. *Business Dynamics: System Thinking and Modeling for a Complex World*. Boston: The McGraw Hill Companies, Inc

Walker, W.E. 1978. A Review of Models in the Policy Process. *The RAND Paper Series*, The RAND Corporation, Santa Monica, California

Walker, W.E., 2000. Policy Analysis: A Systematic Approach to Supporting Policymaking in the Public Sector. *Journal of Multi-criteria Decision Analysis,* Volume 9, pp. 11–27