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Annotated Briefing

NetWeaver™ and GeoNetWeaver™: Decision Support Tools for Sustainable Development

by

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May 1, 2001

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NetWeaver™ and GeoNetWeaver™

DECISION SUPPORT TOOLS FOR SUSTAINABLE DEVELOPMENT

"Facilitating Excellence"™

Annotated Briefing

developed by

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May 1, 2001

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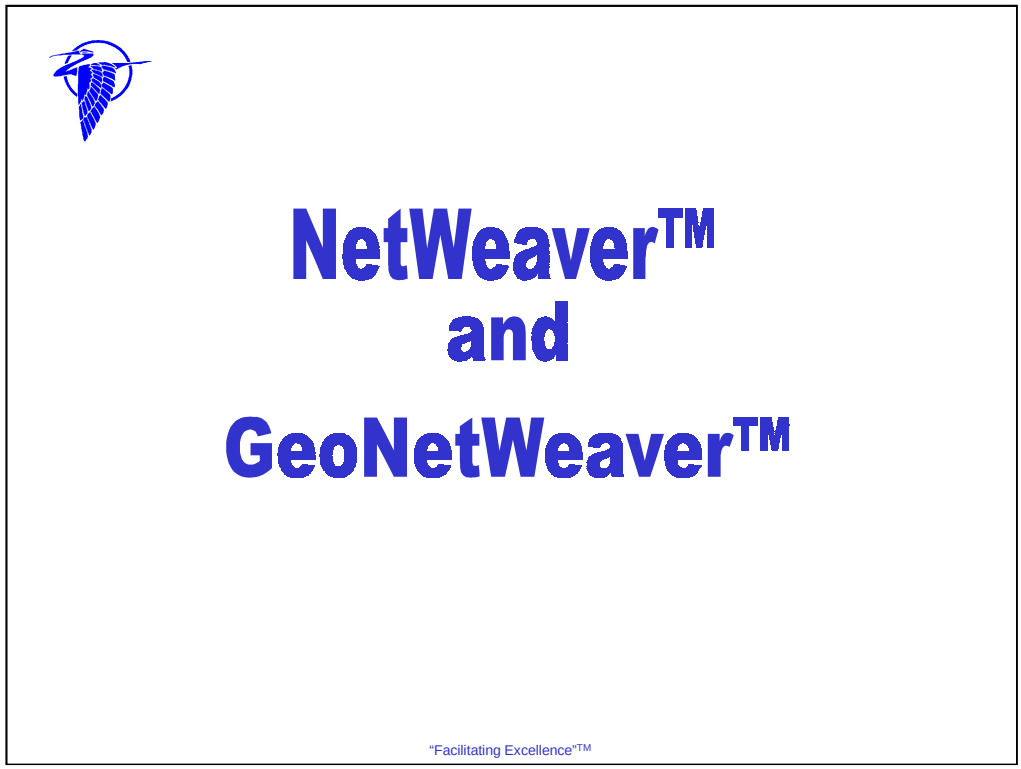

NetWeaver™ is an Artificial Intelligence shell developed by Michael C. Saunders and Bruce J. Miller at The Pennsylvania State University. They originally developed NetWeaver™ for use on complex natural resource issues. NetWeaver™ is now being used by the U.S. Department of the Interior (USDI) Fish and Wildlife Service, the Environmental Protection Agency (EPA),and the U.S. Department of Agriculture (USDA) Forest Service. NetWeaver™ is also being used by USAID's AFR/SD/ANRE to analyze community-based natural resource management (CBNRM). This is the first application in USAID of a new version of NetWeaver™, called GeoNetWeaver™, that represents data in spatially referenced (map) format. The Heron Group, LLC is working with USAID to see how NetWeaver™ and GeoNetWeaver™ can be used to address complex issues in sustainable development.

Part of the challenge of sustainable development is how to handle data, information, and knowledge. All add to an understanding of the nature and magnitude of complexity of systems and the connections and dynamics between and among components—including biophysical, social, economic, political, and organizational—of those systems.

New tools, like NetWeaver™ and GeoNetWeaver™, can assist organizations like USAID in addressing the complexity of systems in which sustainable development takes place. As with other decision support tools, they "support" rather than "replace" decision makers.

The Heron Group, LLC has used NetWeaver™ in the Africa Bureau to analyze the determinants of successful CBNRM (Community Based Natural Resource Management) Initiation. We also have used GeoNetWeaver™ to analyze E&E Bureau's environmental SO 1.6 to look at how a decision support tool can serve planners, managers, decision makers, etc. in strategic planning and performance monitoring efforts.

[NOTE: A set of enlarged slides for all pages is located in the annex of this document for easier viewing of some details.]

Contexts for Sustainable Development Efforts

•complex systems,
•dynamics of change,
•unfixed boundary conditions,
•fuzzy definitions of variables,
•subjective assessments,
•irrational or different kinds of rational beliefs

All these heighten the level of challenge that we, as professionals, have in meeting the real needs of humans and other living and non-living things. New tools, like NetWeaver™ and GeoNetWeaver™ can assist in addressing the challenges confronted in these kinds of contexts.

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The challenges to USAID to achieve sustainable development are daunting. Sustainable development is an extremely complex issue. It has multiple and diverse components that contribute both directly and indirectly to the diversity and complexity of the issue. For example, consider just one element of sustainable development, the environment. Direct and indirect interdependencies with agriculture, water quality and quantity, human health, forestry, and public policy to name just a few exist. In addition, environment also involves numerous interdependent states and processes such as erosion, siltation, loss of habitat, desertification, etc. The challenges to USAID to understand these complex interactions, manage these challenges and at the same time, strive for sustainable development is a monumental task, indeed.

NetWeaver™

uses a

TRANSPARENT,

PARTICIPATORY

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process to:

-represent experts' common understanding

-help them create, manipulate, test, and refine heuristics

-integrate models from across disciplinary fields

-trace the logic structure from data to conclusions

-run and evaluate freshly elicited knowledge "real time"

-help decision makers interpret and utilize outputs

"Facilitating Excellence"™

NetWeaver™

1. represents the experts' common group understanding of a complex system;

2. helps experts create, manipulate, test, and refine heuristics (i.e., decision models or the rules by which professional and indigenous experts understand and respond to a given situation or problem) that demonstrate the logical relationships between and among variables and linkages between the individual parts and the whole;

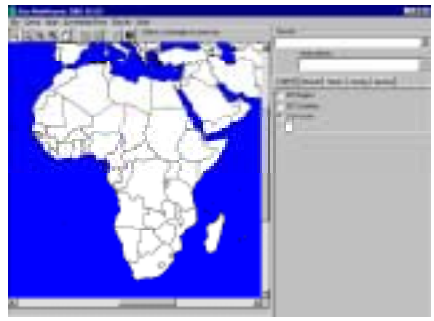
3. integrates models from across disciplinary fields to better reflect the complexity of the actual management decision-making context;

4. provides the ability to trace the logic structure from data to conclusions as well as from conclusions to data;

5. runs and evaluates freshly elicited knowledge "real time" while the domain expert is present;

6. helps decision makers interpret and utilize the outputs of the decision model that provides mathematically robust knowledge about complex problems and that has been used to evaluate less than precise information.

GeoNetWeaver™



uses a

TRANSPARENT,

PARTICIPATORY,

FACILITATED

process to:

-**do full depth analysis of all decision criteria (using the power of its NetWeaver™ foundation) using data across multiple scales and from multiple sources**

-**display spatially referenced data, and not specifically spatially referenced data, in map format**

-**provide a visual presentation similar to a geographic information system**

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GeoNetWeaver™

1. analyzes (using the power of its NetWeaver™ foundation), in full depth, all data across multiple scales (e.g.,1:5,000; 1:50,000) and from multiple sources (e.g., district profiles, soil maps, watershed assessments) for criteria being used for decision making at any and all places;

2. displays spatially referenced data or data not specifically spatially referenced (i.e., it may be from a tabular database at a country level but is not specifically spatially referenced to a given site) in map format;

3. provides a visual presentation of a geographic information system but without the overhead of learning and using a full-blown GIS

A new software product, based on NetWeaver™, GeoNetWeaver™ extends NetWeaver's power to represent knowledge in new ways for managers and decision-makers with its powerful GIS capabilities. GeoNetWeaver™ is a decision support tool that combines the power of object-oriented knowledge-based reasoning with the visual presentation of a geographic information system. However, it does not have the overhead of learning and using a full-blown GIS. The output of a session with GeoNetWeaver™ is a fully featured map displaying knowledge-based outputs. GeoNetWeaver™ conveniently analyzes data across multiple scales (e.g., 1:5,000; 1:50,000) and from multiple sources (e.g., soil type and vegetation type maps, district profiles). Thus, the criteria on which decisions are based can be analyzed in full depth at any and all places.

NetWeaver™ and GeoNetWeaver™ Are Knowledge Base Development Systems

The Knowledge Base is a formal logical representation of entities of interest in some problem area and their relations to one another.

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The components of a Knowledge Base System include an:

-Inference Engine

-Knowledge Base, and

-User Interface

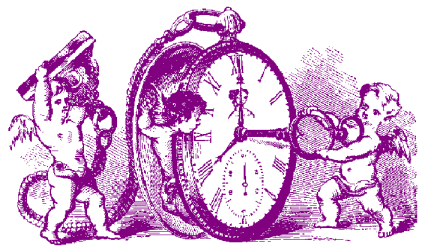
Inference Engine—An Inference Engine is a program library that interprets external data according to the semantics built into a knowledge base by the knowledge base designer. Because the inference engine is integral to the software, dependency networks can be evaluated real-time, with nodes changing color to indicate their changing degrees of "TRUEness". This optimizes the knowledge engineering process since it provides an ability to "peer into" the logical workings of a knowledge network.

Knowledge base—provides a "formal logical specification for the interpretation of data and derived information" (NOTE: Davenport and Prusak (1998. Working Knowledge. Boston: Harvard Business School Press) state that data are "translated" into information when they are contextualized, categorized, calculated, corrected and condensed.). Information is a set of data that makes a difference in the mind of the interpreter. Knowledge is a mix of: 1) framed experience, 2) contextualized information, 3) values, and 4) expert insight. These provide a framework for evaluating new information and experience and incorporating them into new ways of thinking.

User Interface—The computer screen interface that permits the design and evaluation of the knowledge bases.

The NetWeaver/GeoNetWeaver Generic Process

Knowledge Elicitation



Knowledge Representation

Knowledge Verification

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Knowledge Engineers use NetWeaver™ as a tool, working with Domain (Subject Matter) Experts, to build knowledge bases that produce executable models. NetWeaver™ is an interactive, computerized tool that uses the following process:

Knowledge Elicitation--This involves the transfer of area specific knowledge from Domain Experts to the Knowledge Engineer.

Knowledge Representation--This involves the coding of the elicited knowledge by the Knowledge Engineer into NetWeaver™

Knowledge Verification--This involves the testing and verification of how well the incorporated knowledge represents what the Domain Expert knows

Through this process, it is possible for Domain Experts to articulate the logical relationships and linkages between the individual parts and the whole. However, new tools, like NetWeaver™ and GeoNetWeaver™, increasingly are available to condense, process, filter, organize, categorize, and analyze disparate pieces of information and then present it as a new synthesis, as knowledge.

We've used NetWeaver™ to model the dependency networks related to Community Based Natural Resource Management in Africa. As with all NetWeaver™ and GeoNetWeaver™ models, WYSIWYG--What You See Is What You Get—as well as WYDSIWYAG (What You Don't See Is What You Also Get). What we mean by this is that the evaluation window on NetWeaver™ with the bar graph or the map you see in GeoNetWeaver™ are like the face of a watch with the hands on the dial. They are straightforward, easily read, and easily understood with the legend. What the graph or map alone doesn't show are the actual dependency networks, the data, the inference engine, and the analytical tools "inside" that are the foundation of the graphs and maps. Because like any watch, it isn't necessary for everyone to understand how the watch works in order to tell time. The Knowledge Engineers (the cherubs above) know the inner workings. However, it is possible for others to learn how to access the dependency networks/results framework and data by "drilling down" into the model.

Advantages of NetWeaver/GeoNetWeaver Over Other Knowledge Base Systems

1) In contrast to other knowledge base systems, NetWeaver is based on object-oriented fuzzy-logic networks

2) NetWeaver knowledge bases are easier to build, test and maintain because they are very modular

3) Modularity allows the designer to gradually develop complex knowledge bases from simpler ones in small, simple steps.

4) Modularity allows interactive knowledge base debugging at any and all stages of development that expedites the development process

5) Fuzzy logic provides a formal and complete calculus for knowledge representation that is less arbitrary than the confidence factor approach used in rule-based systems.

The developers NetWeaver™ and GeoNetWeaver™ ensured these advantages by designing a knowledge base composed of:

Dependency Networks—they represent topics of interest in a given problem area that will be evaluated when the model is executed

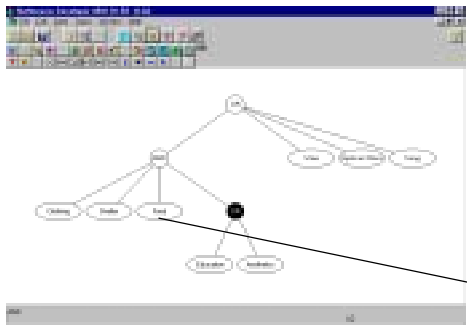
Data links—they can be used to request and evaluate data

Nodes—they specify logical or mathematical relationships among and between dependency networks and data links

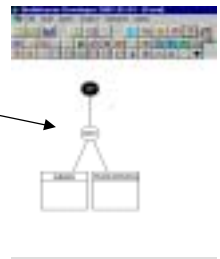
The developers also designed a rigorously object-based system. In NetWeaver™, dependency networks and data links are programming objects that represent, or stand for, real-world objects or concepts. Data links can be used to request data on a real-world object (e.g., forest stand age, human population, degree of perceived cost). Dependency networks typically represent more abstract objects such as suitability (defined in ecological, social, and economic factors) of an area for forest certification (see example on slide 23). For NetWeaver™, these objects, whether concrete or abstract, are things that can be logically or mathematically manipulated. A one-to-one relationship exists between real-world objects and domain expert or user-defined objects in NetWeaver™. NetWeaver™, therefore, makes knowledge representation reasonably straightforward and intuitive.

DEPENDENCY NETWORKS

Graphical depiction (in object-oriented, modular format) of logical relationships between data and conclusion
Example of Quality of Life



Representation of a Data Link for Indicators of Basic Food Needs (i.e., Calories and Vitamin Deficiency)



Note: See full slide in Annex for better view of this dependency network and data link

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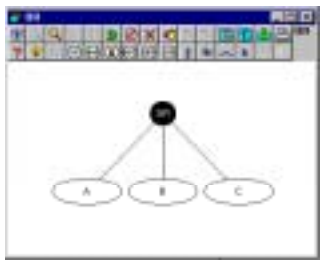
The dependency network plays a central role in NetWeaver™. The Knowledge Engineer uses it to represent the problem to be evaluated by the knowledge base. Networks generally encapsulate human perception, understanding, and/or ability to articulate what things exist in the real world and how those things are connected to one another. For example, roads exist and they interconnect towns with towns, and towns with cities.

A dependency network is a formal logical representation of how system states (including the array of components, structure, relationships, conditions, flows, processes, etc.) at one level of a conceptual model affect or are dependent on antecedent states. An "antecedent state" literally means "coming before something else". In NetWeaver™, the more specific meaning is that all states of the system that possibly can be articulated by experts are represented in the propositional logic of the conceptual framework. This representation will be in the form of a: 1) network (see example above and view other examples in some of the following slides on CBNRM), 2) relational node (e.g., AND, OR), and/or 3) data link that depends on another for its truth value in the sense that the value of the one must be known in order to evaluate that on which it depends. NOTE: Goals are in "ovals" in this diagram and data links are in "boxes".

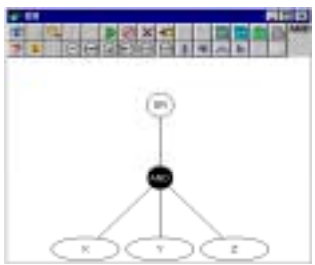
The truth value expresses the degree to which evidence supports or contradicts the proposition(s) that the knowledge engineers, working with domain experts, design the network to test. If all evidence antecedent to a proposition supports the proposition, then the truth value for the network is 1 (i.e., completely TRUE). If all evidence is contrary to that proposition, the truth value for the network is –1 (i.e., completely FALSE). If there is no evidence for or against the proposition, then the truth value is 0 (i.e., Undetermined). Truth values may also be partially true or partially false in NetWeaver™. Among the various reasons for partially true or partially false truth values is that some data needed to fully evaluate the network or node may not have been provided when the evaluation was being performed or that data are actually missing or not available and therefore cannot be supplied. Other more complex reasons are possible as well (see Help function for NetWeaver™ Developer for fuller discussion of this under the topic of "Dependency Networks"). However, in the examples given above, evaluators cannot simply ignore missing data, otherwise the network can become 100% True even without all the data, and evaluators cannot assign missing data a minus 1 (-1) since they don't know if it will be false or not once it is known.

The developers of NetWeaver™ designed the inference engine so that dependency networks have three basic behaviors: 1) they can query antecedent networks on which they depend to determine the state of the latter; 2) they can evaluate their own state, give the state of all their antecedent networks; and 3) they can inform higher level networks that depend on them about their state.

Boolean Operators



TRUE if any path to a node is TRUE
FALSE if all paths to it are FALSE



TRUE only if all paths to a node are TRUE

FALSE if any path to it is false

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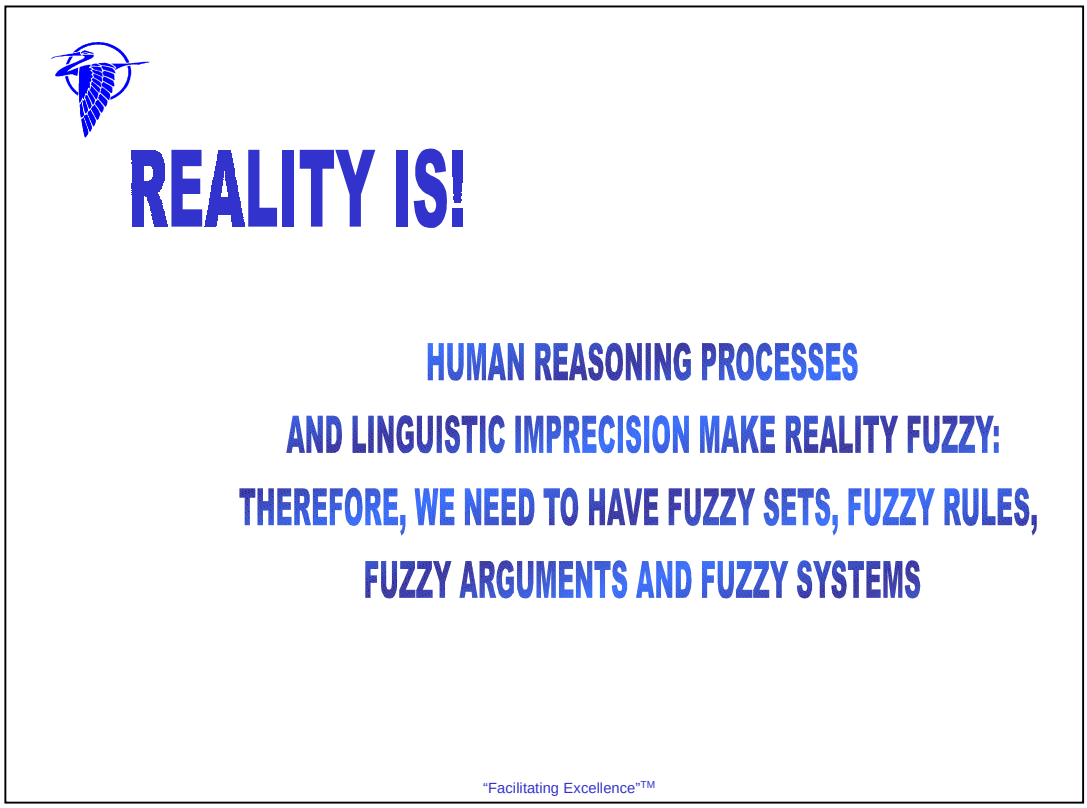
NetWeaver™ and GeoNetWeaver™ use Boolean and other logic and functional (e.g., multiplication, division, etc. that can be used to construct mathematical expressions for calculated data links and comparison) nodes. Domain experts and/or users create nodes to define the logical and mathematical dependencies among problem-specific objects.

The "OR" node at the top is convention. It is a major object in this object-oriented system. An "OR" node is TRUE if any path to it is TRUE. It is FALSE if all paths to it are FALSE.

An "AND" node is often used in developing dependency networks. It is another Boolean operator, e.g., IF this AND this AND this, THEN this. But, the AND node is TRUE only if all paths to it are TRUE. It is FALSE if any path to it is FALSE.

In addition to the "OR" and "AND" nodes, other nodes are found in NetWeaver™ and GeoNetWeaver™. For example, an important recent addition is the "U" node is the "UNION" node. It is a new development, not demonstrated in the current version of the NetWeaver™ CBNRM Initiation Model. The value of the "U" node is the weighted average of the nodes immediately below it. The developers of NetWeaver™ and GeoNetWeaver™ devised this node to give some flexibility when combining results. Effectively its response is somewhere between the "AND" node which is very conservative and the "OR" node which is very liberal. Saunders and Miller found that there are circumstances where you want to be able to combine outputs of nodes in a fashion that let's them all contribute to the result.



One of the greatest challenges for Natural Resource Management (NRM) professionals is modeling human thought and conveying the "mental maps" about the way we think the world works. In fact, these "maps" or models change over time. They are different because of the different values that different perceivers hold. Various ways of representing the way this works include some of the following: straight lines, certain boundaries, curved lines, fuzzy boundaries, crisp sets, fuzzy sets. Linguistic imprecision often leads to erroneous conclusions because of different meanings, and different metrics of those meanings, etc. Fuzzy logic helps deal with those challenges.

Fuzzy Set--A set whose members belong to it to some degree.

Fuzzy Rule—A conditional form of *IF x is A, THEN Y is B*. A AND B are fuzzy sets.

Fuzzy Arguments—The fuzzy argument represents a fuzzy set membership function. Fuzzy membership is "how much" something belongs to a given set. Fuzzy transitions between True and False exist rather than abrupt, knife edge transitions that the "crisp argument" gives. E.g., it is hot when it is 80 degrees F but not when it is 79.9 degrees.

Fuzzy System—A set of fuzzy rules that converts Inputs into Outputs. The closer the Input matches the *IF* part of a fuzzy rule, then the more the *THEN* part applies.

Example of Linguistic Imprecision and a Fuzzy Argument

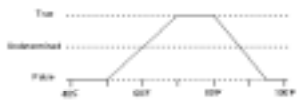
What does warm mean and how do we measure it?

The following is an attempt to quantify the fuzzy argument "warm" for the data link "Temperature".

The transition points:

Temperature	Warm?
50	False
70	True
80	True
95	False

The fuzzy function graph:



The fuzzy function above can be read as: "It is not warm at all below 50° but is starting to become warm. At 70° it is definitely warm. At 80° it is still warm but it is becoming too hot to still be considered warm. At 95° it is too hot to be considered warm any longer."

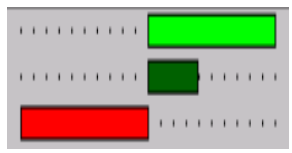
Interpreting the function at some various points:

Temperature	Warm?
32	100% False
60	undetermined
65	50% True
75	100% True
90	33.3% False
100	100% False

NOTE: These degrees of membership would show up in NetWeaver™ and GeoNetWeaver™ in shades from bright green to black to red as per adjacent examples.

Example of Evaluation Windows in NetWeaver™ and GeoNetWeaver™

Brightest Green = 100% TRUE
Black = UNDETERMINED
Brightest Red = 100% FALSE
Colors in between = varying degrees of TRUE, FALSE, or UNDETERMINED



Example Bar Graph from NetWeaver™

Example of map format results in GeoNetweaver™

Fuzziness does not mean that a system or state is All or Nothing nor that it is ambiguous (Allen and Hoekstra). In fact, the example above illustrates a classification dilemma—How do we classify what "warm" is?

Fuzzy set theory provides an formal algebra to deal with a condition, situation, state, etc. that only in part to a defined criterion. And, this algebra "is as particular as that which applies to discrete or crisp sets" (Allen and Hoekstra, 1992. Toward a Unified Ecology. NY: Columbia University Press, p. 295).

Further citing Allen and Hoekstra (pp. 296-297):

> "Multiple-resource management practices are the easiest example to explain the fuzzy description of ecological complexity. Multiple-resource management directed at recreation use is principally a landscape consideration (people mostly go to places and look across vistas, i.e., landscapes). Let us say that it is .8 a landscape question. However, it is also a community consideration, in that vegetation physiognomy is of recreation management importance; say it is .3 a community consideration. Degradation of land through recreational abuse, or degradation making it less useful for recreation both make recreation an ecosystem question in some small way; say it is .1 an ecosystem consideration.
>
> The objective of a multiple-use plan is to develop a systematic suite of management actions in a management area which involves a spectrum of community, ecosystem, and landscape aspects. The above recreational demand would position at .3 on the community axis, .1 on the ecosystem axis, and .8 on the landscape axis. It would be possible to define a particular management action in a three-dimensional community/ecosystem/landscape space. This procedure of fuzzy set assignment of different ecological criteria to a given action will permit a systematic series of fuzzy classifications for a management area, ordered on an increasing scale of the management action."

NetWeaver™ depicts this in a variety of ways—degrees of membership in a fuzzy set on a bar graph, coloration on a map (in GeoNetWeaver™), numerical analysis, data sets, etc.

MULTIVALENT LOGIC
NOT BIVALENT LOGIC

BIVALENT LOGIC

EVERY STATEMENT IS TRUE OR FALSE (E.G., A **OR** NOT A)

MULTIVALENT LOGIC

EVERYTHING IS A MATTER OF DEGREE INCLUDING TRUTH AND SET MEMBERSHIP (E.G., A **AND** NOT A)

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Using NetWeaver™, a knowledge engineer works with subject matter (or domain) experts to better reflect the complexity and "shades of gray" that exist (as opposed to "black and white" representations that most often are given, even though nothing is purely black nor is it purely white) in the contexts and about conditions in which sustainable development and humanitarian assistance take place. It does so by using "fuzzy logic" that all but eliminates bivalent logic (e.g., Yes/No, True/False, or "if we've not totally succeeded then we have totally failed"). Thus, one of the greatest advantages of NetWeaver™ is that it is only necessary to define the very best or the very worst scenario since all other scenario levels are indicated by their level of membership in the "fuzzy" set (e.g., we're 75% toward achieving our goal or we are 30%).

A NRM example of the fuzziness with which we have to deal is when experts articulate a subjective, but highly precise metric upon which managers can make decisions. Experts have determined that a number of factors define what "old growth" in forests is. Some of these include: kind of understory and canopy coverage. Another of the major descriptors of old growth forest is that it is comprised of trees that are 180 years old or older (NOTE: This number is selected for the sake of this discussion only.) This provides the manager with the, perhaps, (pseudo) scientific basis for implementing policy, i.e., legally, the manager cannot cut trees180 year old or older. If this is the case, one might question whether a manager would reject the idea that trees that are 179 years old are "old growth" and proceed to cut them before environmentalists get into litigation that will probably give the trees time to grow to be "old growth" by the time the law suit has ended. The question for the manager might be: Is the 179-year old tree a partial member of what might be old growth class when a less "crisp", more qualitative definition is actually more appropriate. In other words, the fuzzy set may show some degree of TRUTHfulness as compared to some arbitrary, perhaps highly subjective rule—180 years or it's not "old growth"—when it is applied. The arbitrariness of the precise number 180 is a human decision not necessarily a state in nature.

NetWeaver CBNRM INITIATION MODEL

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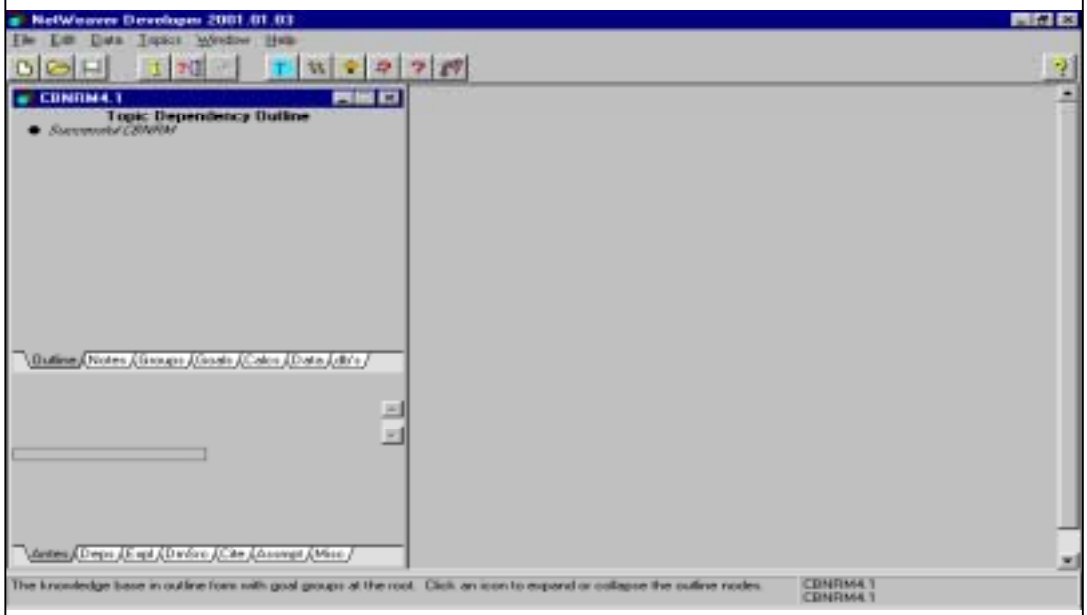
Acknowledgements
for Assistance in Developing
The NetWeaver™ CBNRM Initiation Model

AFR/SD/ANRE and BHR/OFDA provided support of development of this model. Additional acknowledgements go to those who participated in the process of developing this first phase of the model: Paul Bartel (AFR/SD), Mike McGahuey (AFR/SD), Henri Josserand (ARD), John Woodwell (U. Maryland), Bob Winterbottom (IRG), Asif Shaikh (IRG), Yves Prevost (World Bank), David Gibson (Chemonics), and other colleagues at ARD.

More details on the process that this group followed to develop this first phase model of determinants for Initiation of CBNRM are found at www.herongroupllc.com, Report Series No. 105. The next series of slides touch on only a few steps in the process and provide some insights into the power and potential of NetWeaver™ to provide decision makers with relevant, useful and testable data, information, and knowledge on the determinants.

NetWeaver™ Interface
The Outline Folder of the CBNRM Initiation Model



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This slide shows the Knowledge Base Window of NetWeaver™. Every NetWeaver™ knowledge base has only one Knowledge Base Window. In this case with the Outline Folder for CBNRM is open. This shows the array of folders into which objects are added as soon as the Knowledge Engineer creates them.

Outline (shows the basic organizational structure of a knowledge base in this case beginning with "Successful CBNRM" and slide 17 provides the whole outline for the NetWeaver™ CBNRM Initiation Model; provides a useful overview of the complete structure of a knowledge base)

Notes (used to add notes about the knowledge base that are not necessarily directly related to specific network objects. For example, you may want to include ideas that you are not ready to deal with but think might be useful to record for future reference or to put down ideas about the construction and/or potential use of the knowledge base)

Groups = Evaluation Groups (multiple networks to simultaneously view the evaluation of several dependency networks side by side; can access the evaluation window where the bar graph provide results of analysis in green to to black to red conventions of NetWeaver™, as described earlier)

Goals (goals quantify the results of dependency networks as levels of TRUEness; represent the elements and relationships of the problem area identified)

Calcs = Calculated Data Links (data links are simply elementary dependency networks; data input into the knowledge base through the data link; a calculate link transforms input data)

Data = Simple Data Links (the same as above, but a simple data link can read a data evaluation that it passes to another data link without evaluation or it can compute a true value by evaluating the data value against an argument link—see NetWeaver™ Help function about argument links)

Databases (dbs)

Antes = Antecedents (refer to earlier discussion on Slide 8 about Antecedents)

Deps = Dependents (refers to those things that come after or upon which other things require)

Expl = Explanations (for more extensive documentation on an object (e.g., rationale for representing this object in the network, something about the structure of the underlying dependencies)

DmSrc = Domain Source (names of expert(s) who worked with Knowledge Engineer)

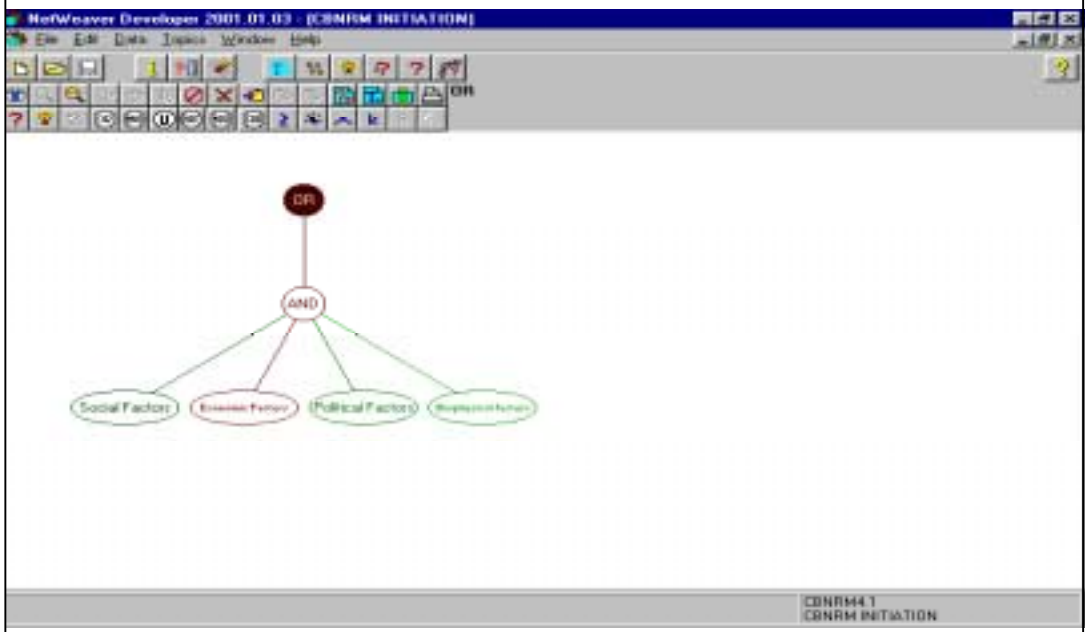
Cite = Citations (relevant literature references)

Assmpt = Assumptions (documentation of assumptions upon which the model is constructed)

Misc = Miscellaneous (anything additional that might be relevant and useful)

These are described in greater detail in the Help section of NetWeaver™ Developer.

Illustrative Array of Preliminary Determinants Articulated by Subject Matter (Domain) Experts



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Example of first level array of potential determinants (i.e., goals in ovals) provided to the Knowledge Engineer by the Domain Experts. **The Summary of Steps in the NetWeaver™ Process to Develop the CBNRM Initiation Model** follow (variations on this process exist):

First Technical Group Meeting—"Herd Milling and Sniffing"

1) Documentation Shared; 2) Common frame of reference established; 3) Discussion between Knowledge Engineers and Domain (Subject Matter) Experts followed; 4) Major Themes were Highlighted

Second Technical Group Meeting—Knowledge Elicitation, Representation, and Preliminary Verification (Scoping and Bounding the Model

1) Introductory Comments Made by Josserand; 2) Introduction of a Model to Work With Proposed by Bartel as part of Scoping; 3) Increased Focus in Preliminary Knowledge Elicitation Stage; 4) Beginning of Questions to Direct Knowledge Representation in NetWeaver™ CBNRM Model; 5) Developing Initial Array of Variables for Exploration and Linkage in the Model; 6) Illustrative Example of One of the CBNRM Determinants Proposed; 7) Further Bounding Occurs; 8) Initial Set of Dependency Networks Developed; 9) Data Links Identified; 10) Iterative Process of Input Proceeds; 11) Initial Verification Process Begins as Elicitation Process Continues: 12) "Capturing" Details to Enhance the Model Begins and Continues

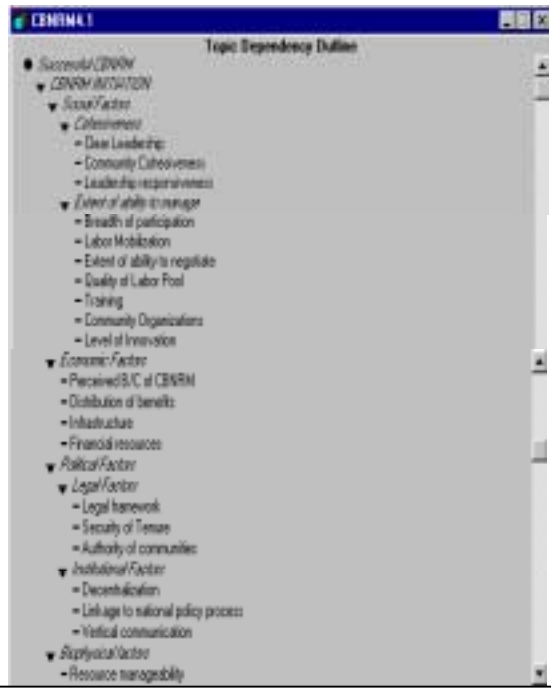
Third Technical Group Meeting—Model Verification by Additional Domain Experts

1) Use of Questionnaire in Verification of the Initial Mode; 2) Lack of Response to Initial Questionnaire Acknowledged and Alternative Sought; 3) Value of a Pre-Test of the Questionnaire; 4) Revised Questionnaire Re-Sent to Selected Respondents

Fourth Technical Group Meeting: Model Verification and Modification

1) Review of Database from Expert Responses to the Revised Questionnaire; 2) Model Modified Based on Sensitivity Analysis of Data and Associated Modification of Questionnaire; 3) Review by Other Members of the Technical Working Group; 4) Discussion about What the NetWeaver™ CBNRM Model Can Tell the Manager/Decision maker—Model Outputs and Products During This Phase; 5) Analysis of the Data; 6) Follow-up Steps and Products to Prepare for Next Phase

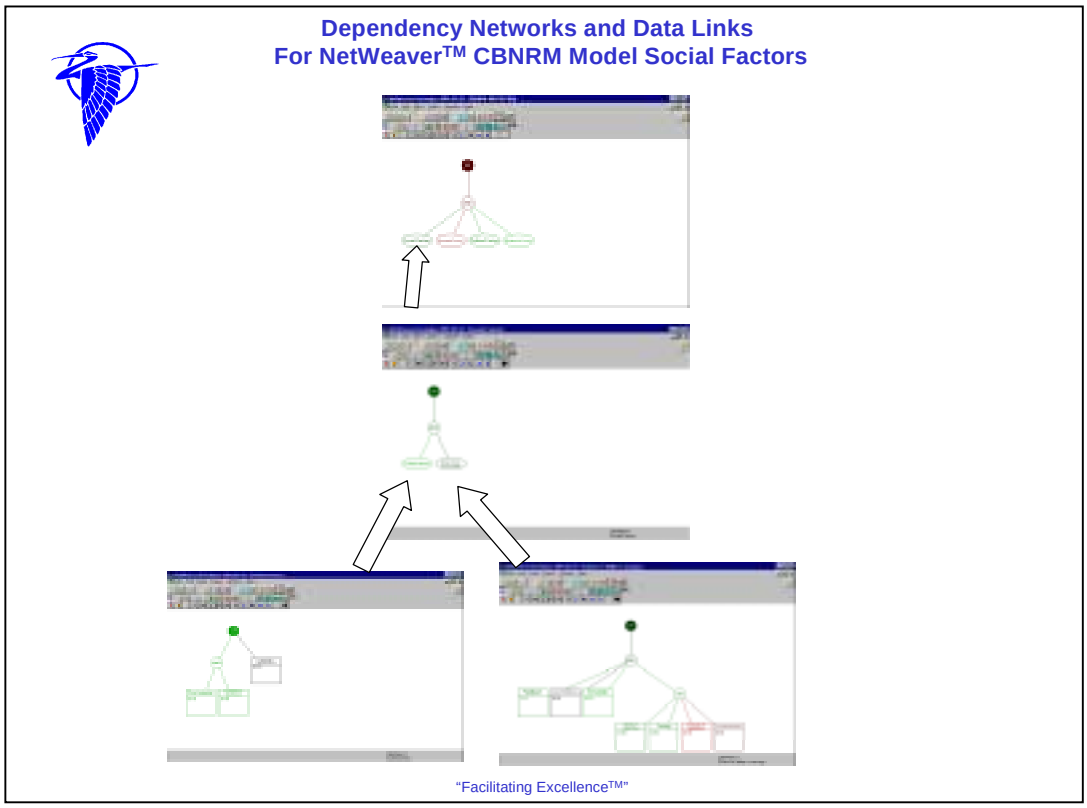
Array of Factors in NetWeaver™
CBNRM Initiation Model
After Development and Sensitivity Analysis



Final array of determinants in this first phase of model development. This shows the Topic Dependency Outline Folder with all the dependency networks identified with the triangle and their data links identified with a hyphen.

Explanations of each of these are found in a Topic Documentation Box for each of the individual topics outlined above. For example, if one looked at an Explanation for the determinant denominated “Cohesiveness”, one could refer to either the model or the explanations in a preliminary questionnaire that was prepared primarily by Dr. Henri Josserand (ARD) to find the following explanation of its meaning: “Cohesiveness is assumed to be a critical determinant of success for a CBNRM activity. CBNRM requires that the community members act jointly to identify or consider a CBNRM opportunity, decide to take action, organize themselves and mobilize their efforts to manage the resources and the enterprise, and agree on the sharing and distribution of benefits. This requires both leadership and a certain amount of cohesiveness. For example, if some social or age/gender-specific groups are left out or slighted, chances of significant or long-term success will be slim. Cohesiveness is not synonymous with homogeneity; some communities are ethnically or socially homogeneous but not very cohesive, while others are cohesive in spite of greater social diversity. A community does not have to be very egalitarian to be cohesive, but wide disparities in access to basic resources (e.g. land, water) and in social status are good signs that a community would have difficulty managing a CBNRM activity and sharing its benefits broadly. A good indicator of cohesiveness is whether access to basic education, training and extension services are accessible to members of the community's various ethnic, social, and gender/age specific classes.”

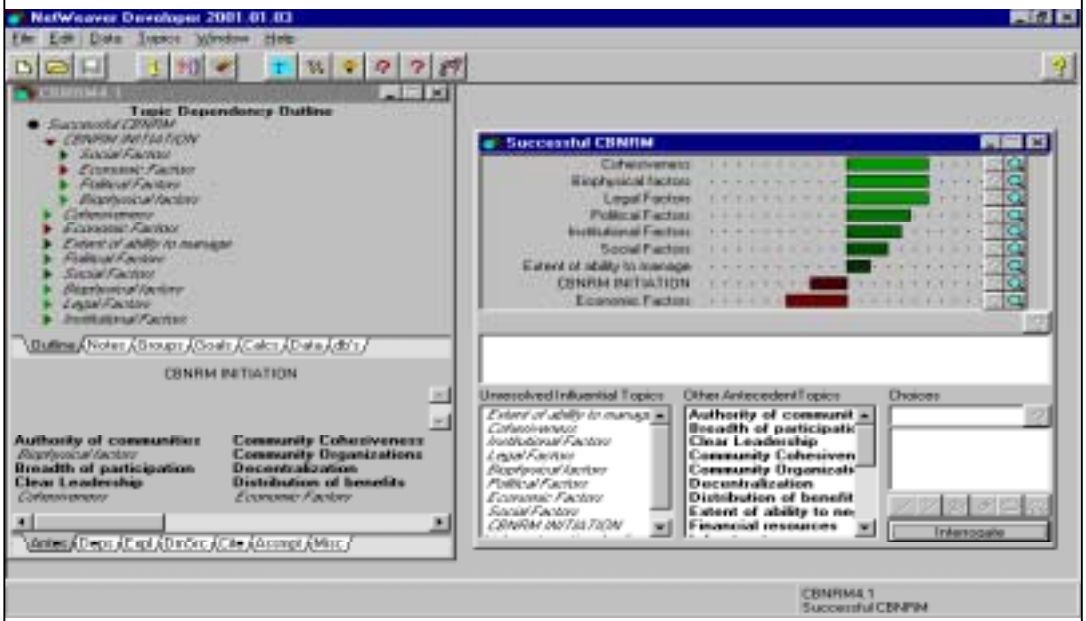
An example of the dependency network for social factors follows on the next slide.



The highest level dependency network for determinants of CBNRM Initiation included: Social Factors, Economic Factors, Political Factors, and Biophysical Factors. NetWeaver™ analysis of data obtained on Social Factors indicates that this set of determinants is 29.98 % TRUE. The colors in these screen captures of NetWeaver™ CBNRM Initiation Social Factors shows coloration from bright green to black to red that is the convention in NetWeaver™ display. Also note that in the next few lines, each element of the dependency networks demonstrated in the screen captures above have numbers arising from the NetWeaver™ analysis of the data during the first phase of model development. These numbers in percentage illustrate how data can become information—degrees of TRUTH— for discussion and converted into knowledge for decision making about this particular set of determinants of CBNRM Initiation. This is one of a variety of ways that NetWeaver™ provides data for decision support. Going directly into the NetWeaver™ CBNRM database is another example of how data are made available in this tool. "Drilling down" into this network, looking solely at social factors in this example, one finds a second level dependency network identifying Cohesiveness [60% TRUE] and Extent of Ability to Manage [17.5% TRUE]. Drilling further down, one finds data links for cohesiveness that include measures for cohesiveness (described in detail on the previous slide) as being clear leadership [60% TRUE] AND community cohesiveness [60% TRUE] OR leadership responsiveness [UNDETERMINED]. Drilling further into the ability to manage data links, one finds: Breadth of Participation [40% TRUE] AND Labor Mobilization [UNDETERMINED] AND Extent of Ability to Negotiate [60% TRUE] AND Quality of Labor Pool [40% TRUE] OR Training [40% TRUE] OR Community Organization [60% FALSE] OR Level of Innovation [20% FALSE].

Perhaps trying to address some of the determinants that are negatively affecting the Ability to Manage might be a consideration for decision makers given this analysis.

NetWeaver™
Topic Dependency Outline and Evaluation Window



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This slide provides an array of information for decision support. The Topic Dependency Outline is open to the left. It provides a list of the primary goal groups that one can then see on the right side in the form of the evaluation window with the bar graphs. The colors in the Dependency Outline provide some immediate cues and each of these can be clicked on to open a Dependency Network. When linked to the data from the 13 responses to the questionnaire that is batch processed, the analysis of the data from these questionnaires appears in the evaluation window.

The following are the results of the data analysis for the key determinants of CBNRM Initiation in this first phase of this effort:

Cohesiveness – 60% TRUE

Biophysical Factors – 60% TRUE

Legal Factors – 60% TRUE

Political Factors – 47% TRUE

Institutional Factors – 40% TRUE

Social Factors – 29.98 % TRUE

Extent of Ability to Manage – 17.5% TRUE

CBNRM INITIATION – 26.68 % FALSE

Economic Factors –45.3% FALSE

There are several important cues to interpreting the analysis of the data. It appears that CBNRM INITIATION at the 13 different sites reported on in the questionnaires was somewhat questionable. One of the main problem determinants was Economic Factors. However, it would be important to also explore where problems might exist for Social Factors and for the Extent of the Ability to Manage. Questions about the indicators being used might be important to raise. Questions about the reliability of the questionnaires is also an important question to consider, but given the "efficiency" of using questionnaires instead of having the Knowledge Engineers go through a face-to-face facilitated process, this is perhaps the best available information at this point in time. But, other questions about the exact nature of the problems with any of the determinants needs to be explored. NetWeaver™, like many other tools, can be used by decision makers to understand what is happening, but more needs to be done to explain the "why" of what is happening. However, using the example of Economic Factors, a decision maker may decide that before initiating a CBNRM effort that due consideration and support to economic factors must be taken or some degree (perhaps total) failure is likely to occur. These and many other questions may be useful for discussions among managers and decision makers as a tool like NetWeaver™ provides a framework and analytical basis on which decisions can be made.

NetWeaver CBNRM Model Outputs

Output for Dataset 1

Output for Dataset 2

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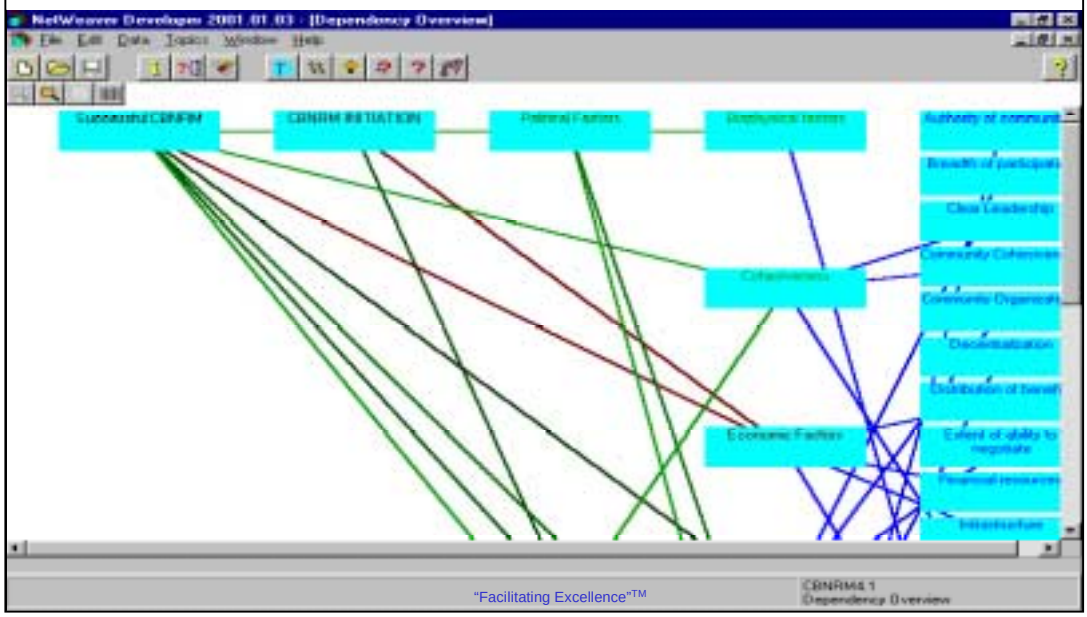
These examples are screen captures of the NetWeaver™ CBNRM model output for two datasets. Output for Dataset 1 represents a response to a CBNRM activity in Country X and Output for Dataset 2 represents a response to a CBNRM activity in Country Y. These have real data from responses to the questionnaire, we are maintaining confidentiality here, as agreed to with respondents to the questionnaire.

In the Output for Dataset 1, we see that the CBNRM INITIATION bar is bright red and to the left of the midpoint of the chart. This indicates that a successful initiation is not likely. Additional information is provided by the presence of red bars for Institutional, Economic, Political, and Legal factors indicate areas. These would have to be greatly improved upon if success is to be achieved. In the model itself, it would be possible to trace the problem areas through the dependency network and determine more precisely which determinants were contributing to the negative analysis of this particular CBNRM activity. This could tell the field manager or decision maker whether to re-allocate resources in certain determinants or even perhaps to terminate the project if too many resources would be necessary to make this effort successful.

In the Output for Dataset 2, we see a vastly different portrayal. On the one hand, in this case, we see green bars going to the right. These indicate strength at the project site in Community Cohesiveness and in the Economic, Legal, Political, Institutional, and Biophysical factors. On the other hand, we see that Social factors are indeterminate and that the Extent to Ability to Manage is slightly negative. The interaction between these positive, neutral, and negative factors have contributed to a CBNRM INITIATION bar that is only slightly to the right and black. This indicates that it is only slightly positive. This means that, although most of the determinants are positive, more attention will have to be devoted to improving extent of ability to manage and improving social factors at this site.

NetWeaver™ Dependency Overview Demonstrating Linkages Between Determinants and their Contribution to Achievement of Some Degree of CBNRM Success



The Dependency Overview provides a graphical browser of the dependency networks. This Dependency Overview illustrates the connections/linkages between CBNRM determinants (objects) in the knowledge base. Clicking on a topic button, like "Successful CBNRM" highlights the linkages for that topic. As with other windows of NetWeaver™, you can see the red and green and blacker colors that demonstrates degrees of TRUEness, FALSEness and Undetermined. This is only a small portion of the Dependency Overview. When the model is executed on a computer it is possible to scroll up, down, to the side to view all the linkages. And, clicking on the topic button opens the window for that topic. In other words, it will take you back to the Evaluation Window with the bar graphs, or to the dependency networks that are related to the topic, and/or to the data links.

Other Potential Applications of NetWeaver™ and GeoNetWeaver™

-Reduction of impact from natural disasters
-Impact of AIDS on human resources for NRM
-Environmental trends analysis
-Ecosystem management
-Data needs assessment
-Forest certification
-Analysis of water quality for development permit process
-Results-oriented strategic planning
-Performance monitoring

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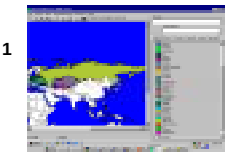
Why use knowledge-based reasoning (application of formal logic) in NRM?—It provides logical and mathematically robust solutions that can be used to evaluate more imprecise information.

Why are Knowledge-based systems helpful in NRM problem domains?

1) Ecosystems are broad, complex, and involve abstract (and imprecisely defined) concepts such as health, sustainability, resilience).
2) Assessment of all these depend on multiple, diverse, and interdependent states and processes.
3) Integrated management of the natural resource base presupposes that integrated analysis and understanding are possible
4) That analysis and understanding increasingly is believed to be needed for specific and multiple spatial scales (e.g., landscape)
5) Subject Matter Experts (SMEs) can typically express in some general way, their understanding of these states and processes, entities and their logical relationships.

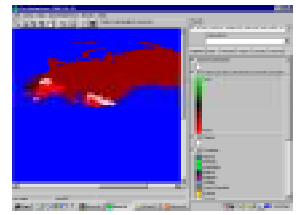
GeoNetWeaver™ :
An Application in Results-Oriented Planning and Monitoring

1



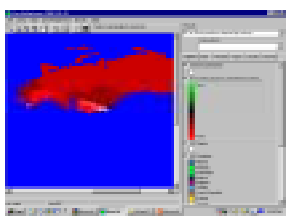
GeoNetWeaver™ View of Eastern Europe & Eurasia Region

2



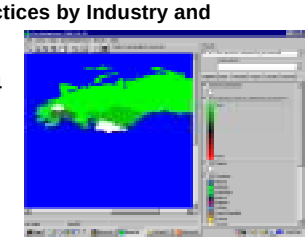
Results of GeoNetWeaver™ Analysis of Data by Country for IR3a (Adoption of Best Practices by Industry and Public Sector Combined)

3



Results of GeoNetWeaver™ Analysis of Data by Country for IR3a for Industry

4



Results of GeoNetWeaver™ Analysis of Data by Country for IR3a for Public Sector

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Screen Capture 1—GeoNetWeaver™ view of E&E Region, with each country in color (to differentiate country but has no meaning beyond that in the example of the analysis in red to green that follows).

Screen Capture 2—This is just one of many possible examples of the results of this GeoNetWeaver™ analysis, specifically IR 3a—Best Practices Adopted by the Industrial and Public Sector. This shows the GeoNetWeaver™ analysis of data by country on progress toward achievement of results when you combine the data for both industry and public sector efforts to adopt new practices. You can see some changes in color in terms of less overall bright red as compared to the previous slide that shows results at the overall SO level. Here we see a country like Russia seems to be making some progress when we look at the combined data. Poland still remains in the category of almost making positive progress. More countries here, however, show they they fit into the category of "data dissatisfaction" (i.e., where white appears as a new feature of GeoNetWeaver™). But, it is important to look at differences when data are disaggregated—i.e., by industrial sector and public sector, as per the next two slides. They tell a different story than this one because of the process of disaggregation.

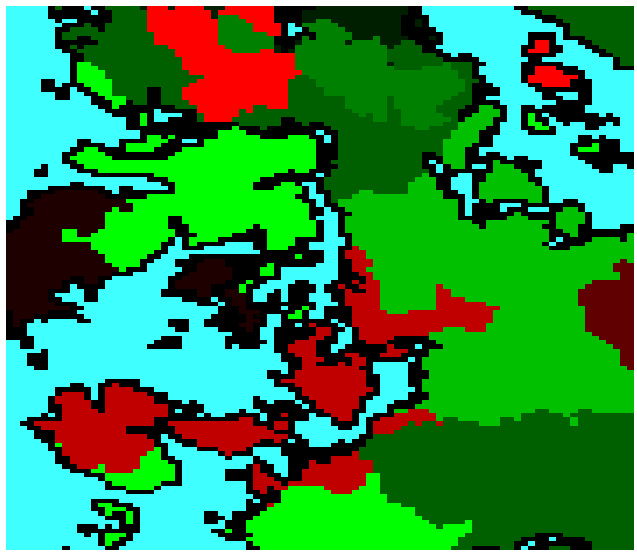
Screen Capture 3—The analysis of data for the industry sector show some significant differences from the previous slide (i.e., the one that shows the results when data for industry and public sector efforts to adopt new practices are combined). As before, even when disaggregated, most of the countries are on the bright red to darker red side. There seems to be less "data dissatisfaction" on the part of Domain Experts relative to the data portrayed here.

In general, this map provides decision makers and managers with an opportunity to discuss issues related to where and how progress might be made on a variety of fronts in the industrial sector. They may also want to discuss issues such as reallocation of resources from other IRs to make progress in this sector overall or perhaps only in given countries. Or they may decide that resources should not be allocated to this sector at all, etc.

Screen Capture 4—When disaggregated from the industrial sector, the data for the public sector show a considerably different picture. Things look pretty good since so many countries graphically appear to be on the more positive side (as portrayed by different colors of green, with the brightest shade being the most "true" or positive).

Decision makers may decide that no further effort needs to be expended in this sector. However, looking at the indicators that have been used may provide decision makers with an opportunity to reflect on what these results really mean in terms of non-capital city populations which the indicators for the public sector part of this IR measure.

Potential Use of GeoNetWeaver for Forest Certification in the SE



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Example of how a GeoNetWeaver™ map might show level of Certification standards being met in a given area in the Southeastern (SE) U.S. where multiple ownerships (e.g., State Park, National Forest, private company forest, small forest landowners) are present. The blue shows water. The rest of the area is all forested, but with a variety of permitted land uses that might or might not allow certification of all these contiguous forested lands. The different colors do NOT show different ownerships. They demonstrate how an analysis of a given geographic area might demonstrate the "overlay", if you will, of ecological, economic, and social criteria. Where you see bright red, there might be a strong indication that most if not all of your criteria cannot be met for any number of reasons (but "drilling" into the database, you would be able to identify whether it is ecological, social, or economic factors or a combination of some or all causing the problems that would prevent certification). These bright red areas would probably show up as close to 100% false on GeoNetWeaver™. The darker red is moving a bit more in the direction of being less false than the bright red, but they send up flags that there may be substantial problems in at least one of your categories of criteria, e.g., there may be strong social opposition because people want this state forest land available for All Terrain Vehicles (ATVs), there may be 1994 cutovers, or whatever. These definitely do not fit on the fuzzy ramp that the experts would have established. The almost black color indicates that these are indeterminate on the scale. There may not be enough quantitative and/or qualitative data to know for sure whether these would meet all standards; the data may not be very good; there may be a gap in data that might need to be filled before these areas could be certified; etc. The different shades of green show different degrees of TRUENESS. In other words, they look like they are meeting standards (measured by indicators) to some greater degree. The darker green are definitely moving upward on the fuzzy ramp that the experts have defined to the point where the brightest green probably reflects 100% TRUE or that the area has definitely met all criteria/standards, i.e., the ecological, economic and social basis for forest certification.

You might want to do some "what if games"/scenarios on certain areas to see what it might take to get the red ones, for instance, to move toward the green side. For example, what if a forest cut criterion was not imposed on the SE region, what would that mean for the areas that are red because the indicators show that to be the major problem (i.e., that cuts from 1994 affect many cut over areas from even being considered for certification)? Going into the database and changing the numbers for this kind of exercise is quite possible for trained end users, e.g., decision makers, certifiers, land managers.

The GeoNetWeaver™ generated map can show contiguous lands and what the patterns of meeting certification standards might be. Over time the indicators might show that new areas can be brought into the broader certification area. Those same indicators might also, over time, show trends in one of your ecological, social, and/or economic factors where new problem areas may be affecting certification across the landscape (e.g., a new road has been built, new zoning policy permits development that had previously not been permitted).

for more information contact
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ANNEX

Full Slides of Annotated Briefing for easier Viewing

NetWeaver™ and GeoNetWeaver™

DECISION SUPPORT TOOLS FOR SUSTAINABLE DEVELOPMENT

NetWeaver™
and
GeoNetWeaver™

Contexts for Sustainable Development Efforts

•complex systems,
•dynamics of change,
•unfixed boundary conditions,
•fuzzy definitions of variables,
•subjective assessments,
•irrational or different kinds of rational beliefs

All these heighten the level of challenge that we, as professionals, have in meeting the real needs of humans and other living and non-living things. New tools, like NetWeaver™ and GeoNetWeaver™ can assist in addressing the challenges confronted in these kinds of contexts.

NetWeaver™

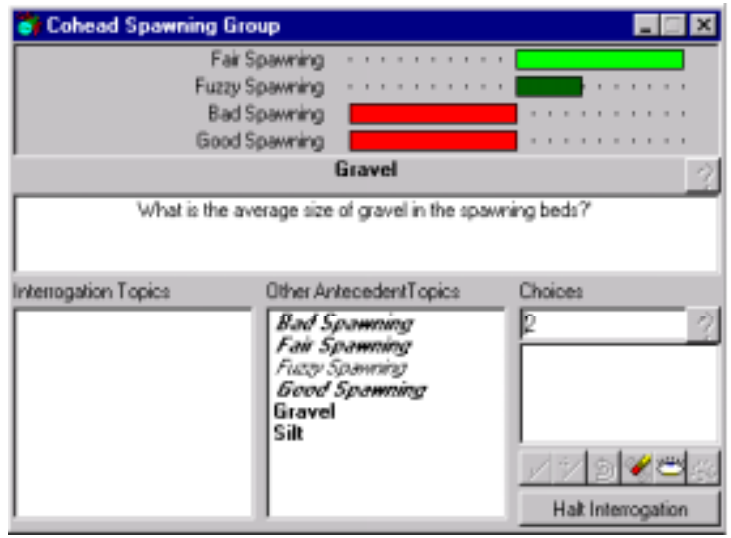
uses a

TRANSPARENT,

PARTICIPATORY

FACILITATED

process to:



-**represent experts' common understanding**

-**help them create, manipulate, test, and refine heuristics**

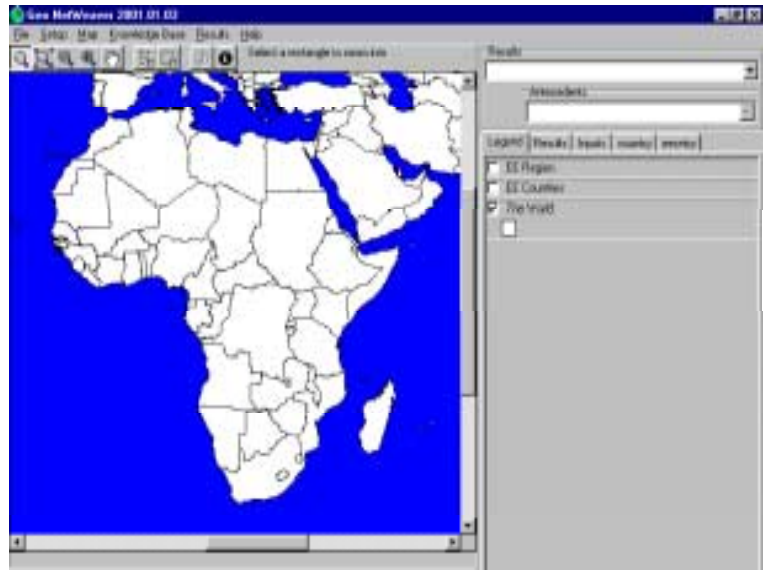
-**integrate models from across disciplinary fields**

-**trace the logic structure from data to conclusions**

-**run and evaluate freshly elicited knowledge "real time"**

-**help decision makers interpret and utilize outputs**

GeoNetWeaver™



uses a

TRANSPARENT,

PARTICIPATORY,

FACILITATED

process to:

-**do full depth analysis of all decision criteria (using the power of its NetWeaver™ foundation) using data across multiple scales and from multiple sources**

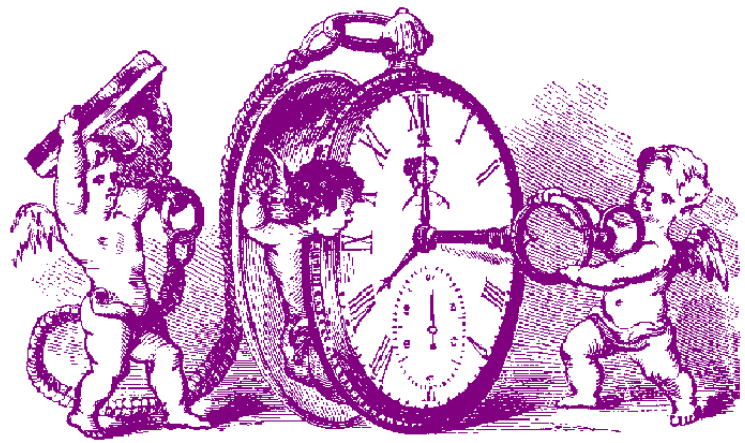
-**display spatially referenced data, and not specifically spatially referenced data, in map format**

-**provide a visual presentation similar to a geographic information system**

NetWeaver™ and GeoNetWeaver™ Are Knowledge Base Development Systems

The Knowledge Base is a formal logical representation of entities of interest in some problem area and their relations to one another.

The NetWeaver/GeoNetWeaver Generic Process



Knowledge Elicitation

Knowledge Representation

Knowledge Verification

Advantages of NetWeaver/GeoNetWeaver Over Other Knowledge Base Systems

1) In contrast to other knowledge base systems, NetWeaver is based on object-oriented fuzzy-logic networks

2) NetWeaver knowledge bases are easier to build, test and maintain because they are very modular

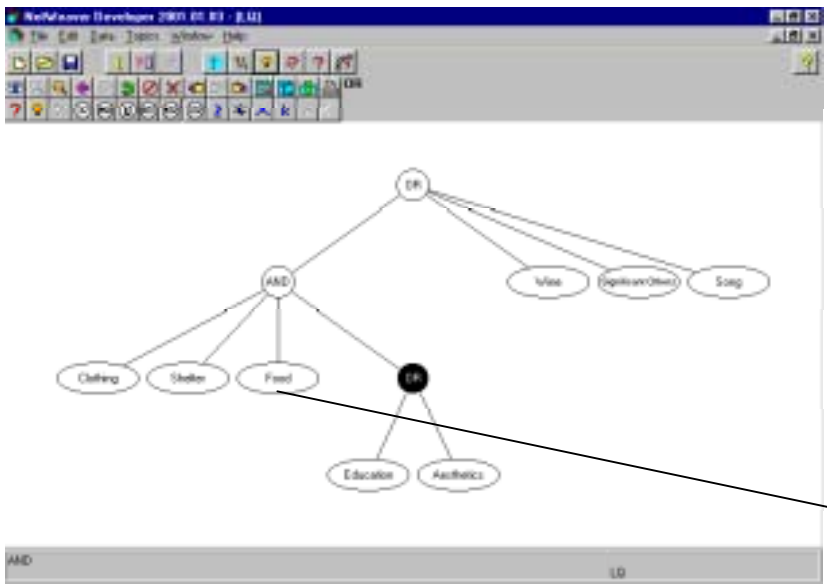
3) Modularity allows the designer to gradually develop complex knowledge bases from simpler ones in small, simple steps.

4) Modularity allows interactive knowledge base debugging at any and all stages of development that expedites the development process

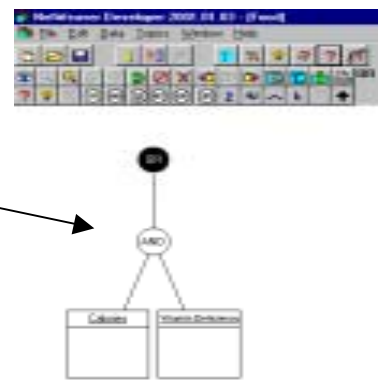
5) Fuzzy logic provides a formal and complete calculus for knowledge representation that is less arbitrary than the confidence factor approach used in rule-based systems.

DEPENDENCY NETWORKS

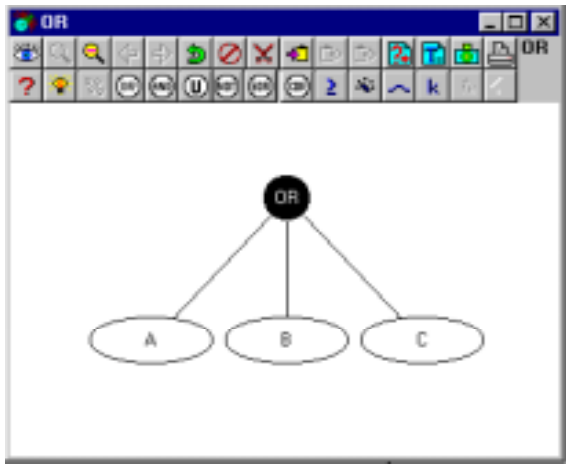
Graphical depiction (in object-oriented, modular format) of logical relationships between data and conclusion
Example of Quality of Life



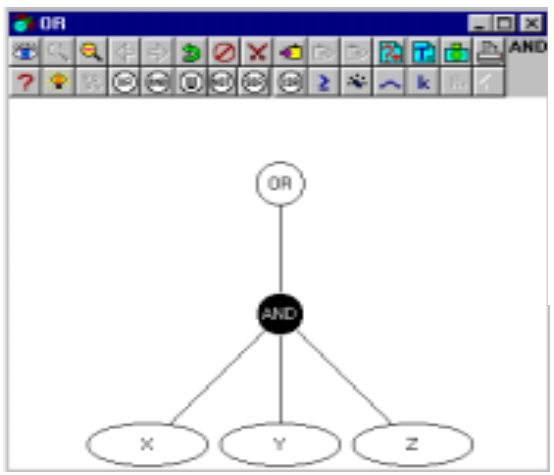
Representation of a Data Link for Indicators of Basic Food Needs (i.e., Calories and Vitamin Deficiency)



Boolean Operators



TRUE if any path to a node is TRUE
FALSE if all paths to it are FALSE



TRUE only if all paths to a node are TRUE

FALSE if any path to it is false

REALITY IS!

HUMAN REASONING PROCESSES

AND LINGUISTIC IMPRECISION MAKE REALITY FUZZY:

THEREFORE, WE NEED TO HAVE FUZZY SETS, FUZZY RULES,

FUZZY ARGUMENTS AND FUZZY SYSTEMS

REALITY IS!

HUMAN REASONING PROCESSES

AND LINGUISTIC IMPRECISION MAKE REALITY FUZZY:

THEREFORE, WE NEED TO HAVE FUZZY SETS, FUZZY RULES,

FUZZY ARGUMENTS AND FUZZY SYSTEMS

Example of Linguistic Imprecision and a Fuzzy Argument

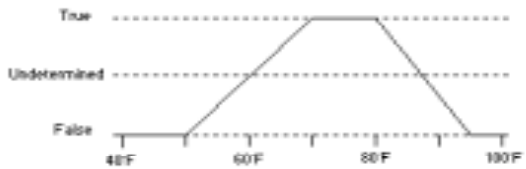
What does warm mean and how do we measure it?

The following is an attempt to quantify the fuzzy argument "warm" for the data link "Temperature".

The transition points:

Temperature	Warm?
50	False
70	True
80	True
95	False

The fuzzy function graph:



The fuzzy function above can be read as: "It is not warm at all below 50° but is starting to become warm. At 70° it is definitely warm. At 80° it is still warm but it is becoming too hot to still be considered warm. At 95° it is too hot to be considered warm any longer."

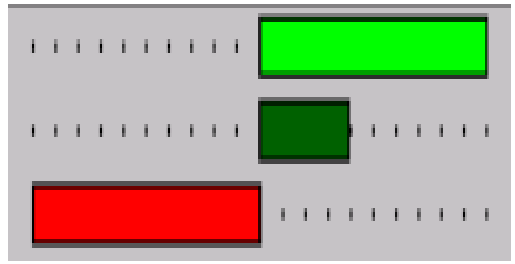
Interpreting the function at some various points:

Temperature	Warm?
32	100% False
60	undetermined
65	50% True
75	100% True
90	33.3% False
100	100% False

NOTE: These degrees of membership would show up in NetWeaver™ and GeoNetWeaver™ in shades from bright green to black to red as per adjacent examples.

Example of Evaluation Windows in NetWeaver™ and GeoNetWeaver™

Brightest Green = 100% TRUE
Black = UNDETERMINED
Brightest Red = 100% FALSE
Colors in between = varying degrees of TRUE, FALSE, or UNDETERMINED



Example Bar Graph from NetWeaver™

Example of map format results in GeoNetweaver™

MULTIVALENT LOGIC
NOT BIVALENT LOGIC

BIVALENT LOGIC

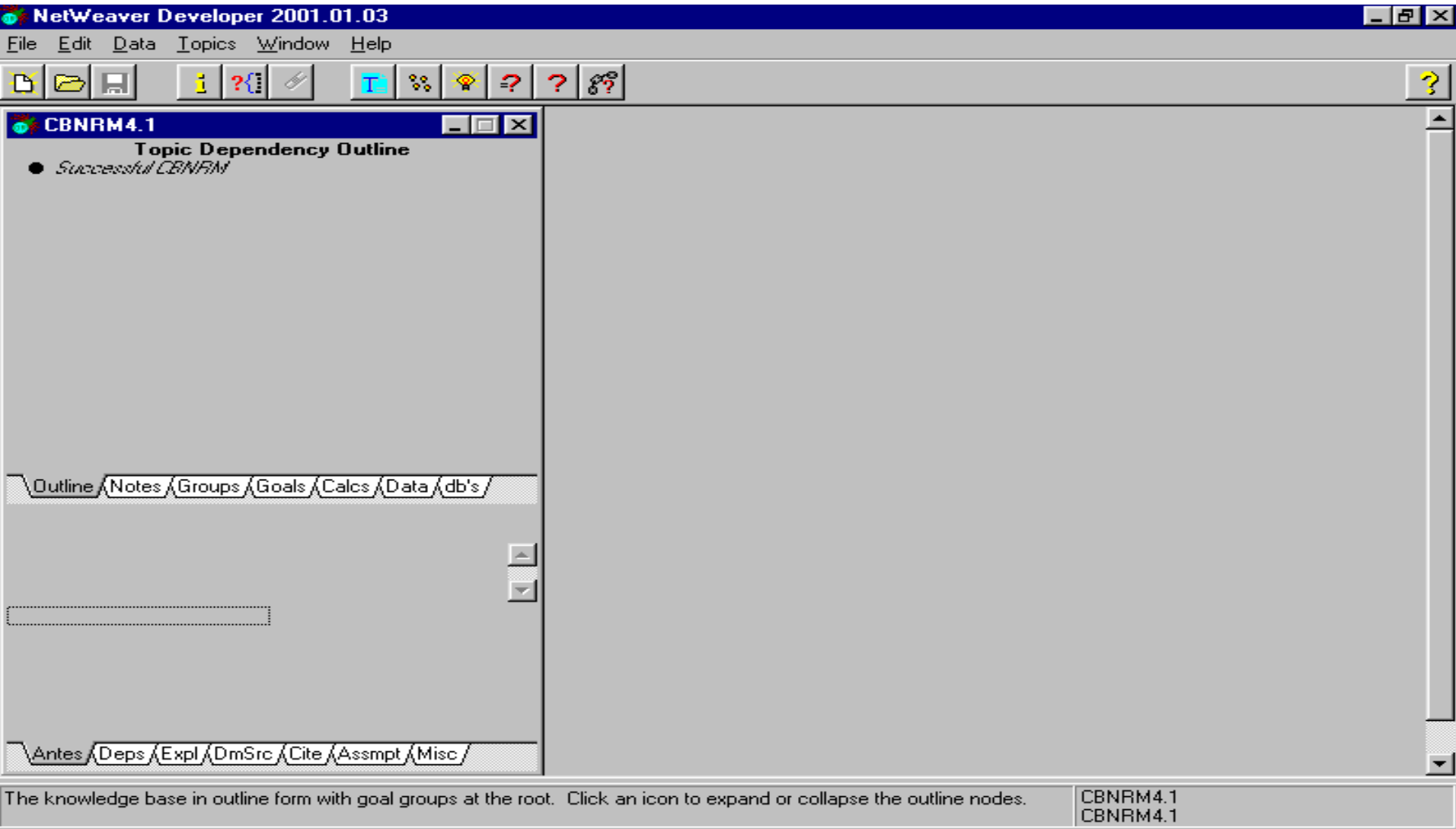
EVERY STATEMENT IS TRUE OR FALSE (E.G., A **OR** NOT A)

MULTIVALENT LOGIC

EVERYTHING IS A MATTER OF DEGREE INCLUDING TRUTH AND SET MEMBERSHIP (E.G., A **AND** NOT A)

NetWeaver CBNRM INITIATION MODEL

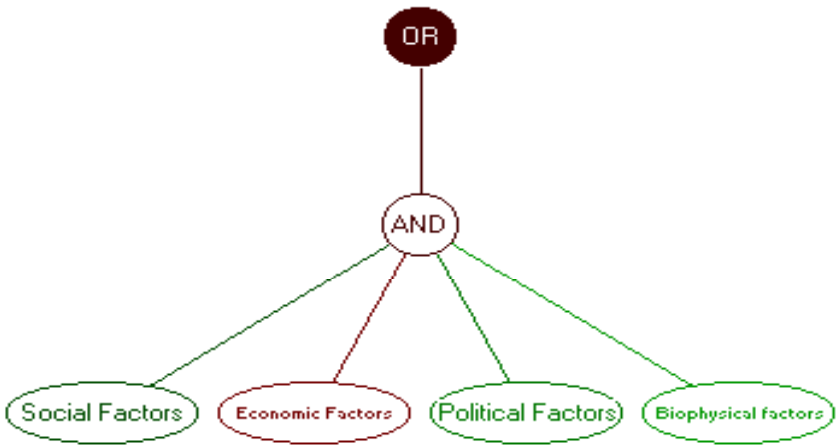
NetWeaver™ Interface
The Outline Folder of the CBNRM Initiation Model



Illustrative Array of Preliminary Determinants Articulated by Subject Matter (Domain) Experts

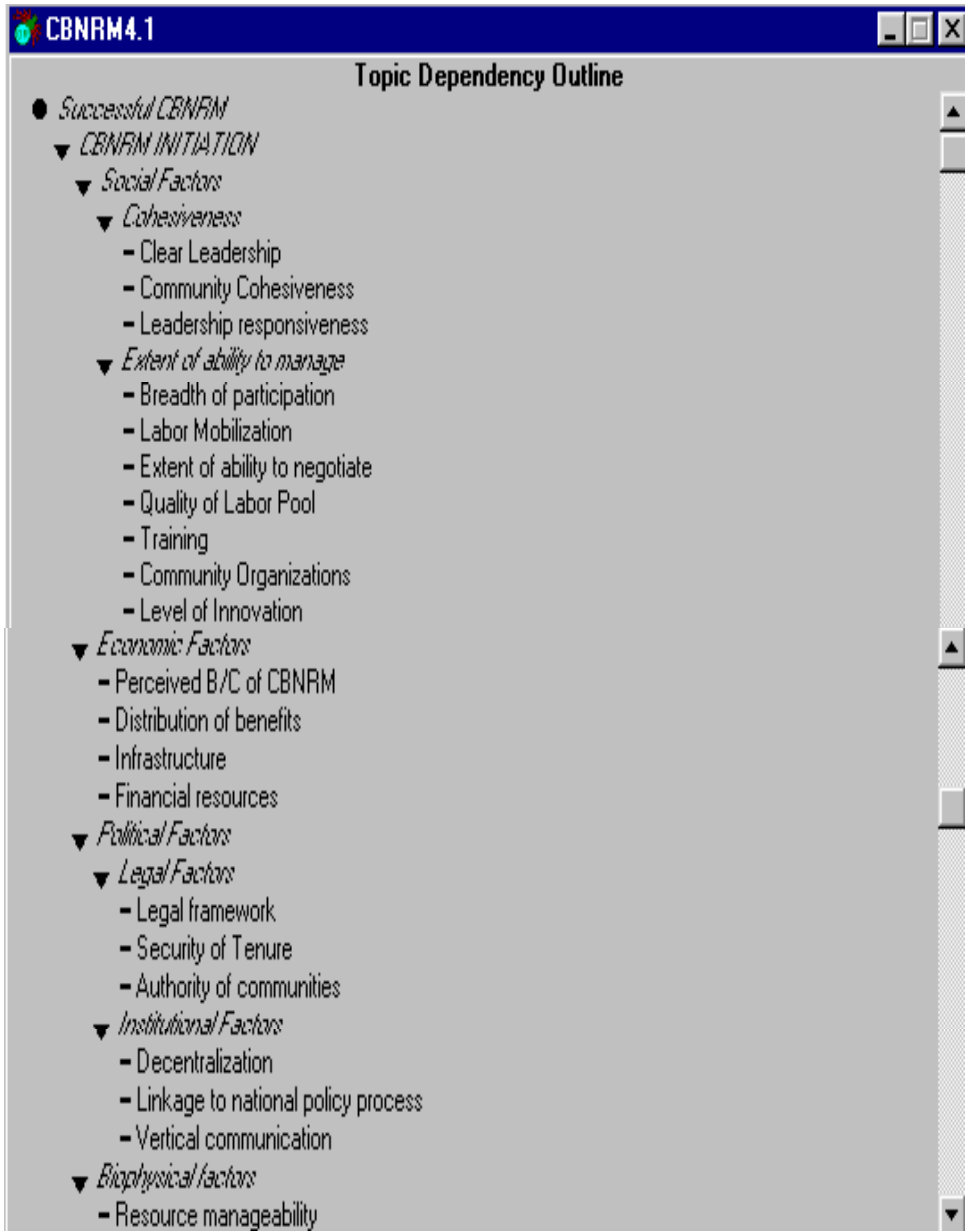
NetWeaver Developer 2001.01.03 - [CBNRM INITIATION]

File Edit Data Topics Window Help

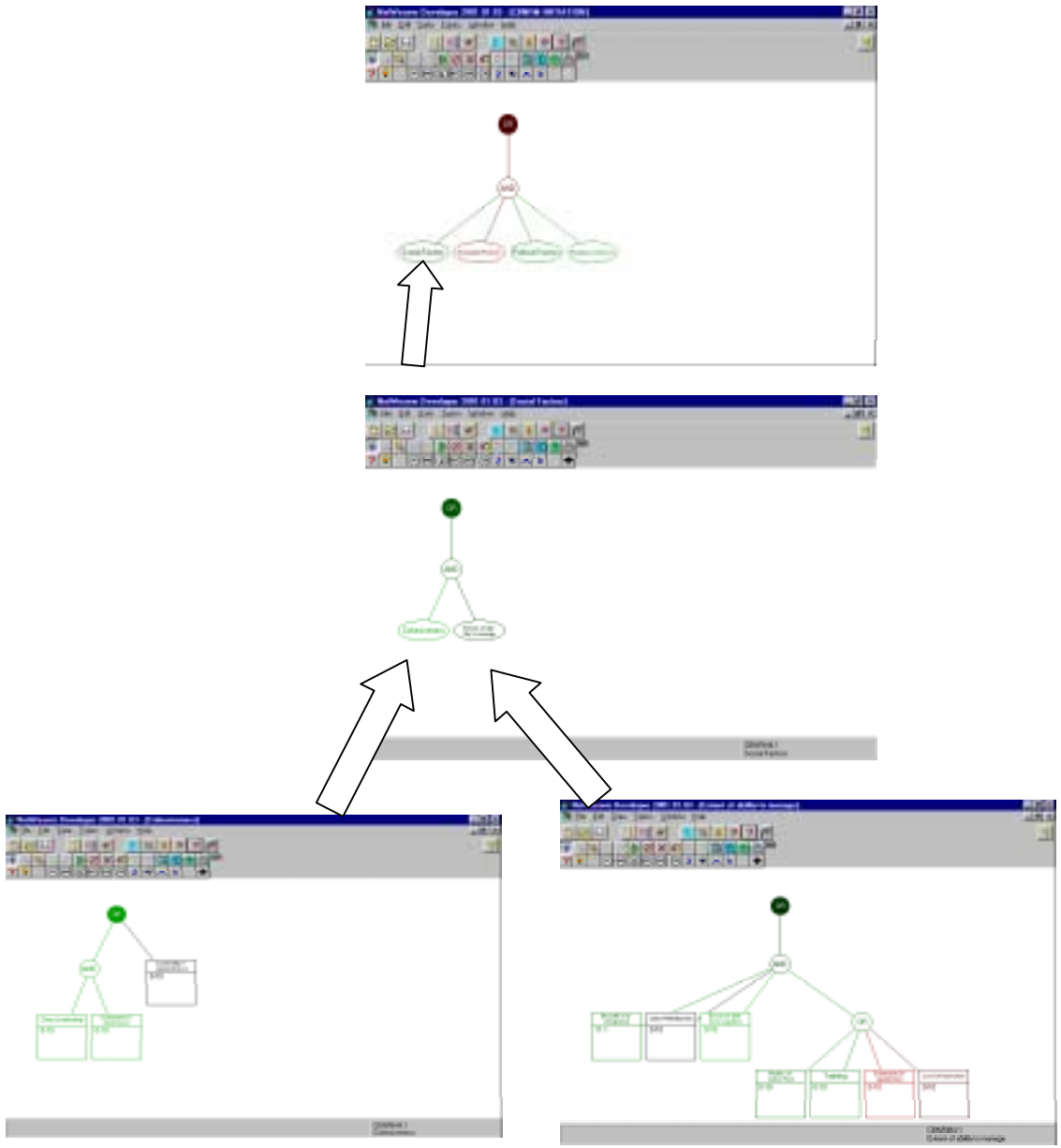


CBNRM4.1
CBNRM INITIATION

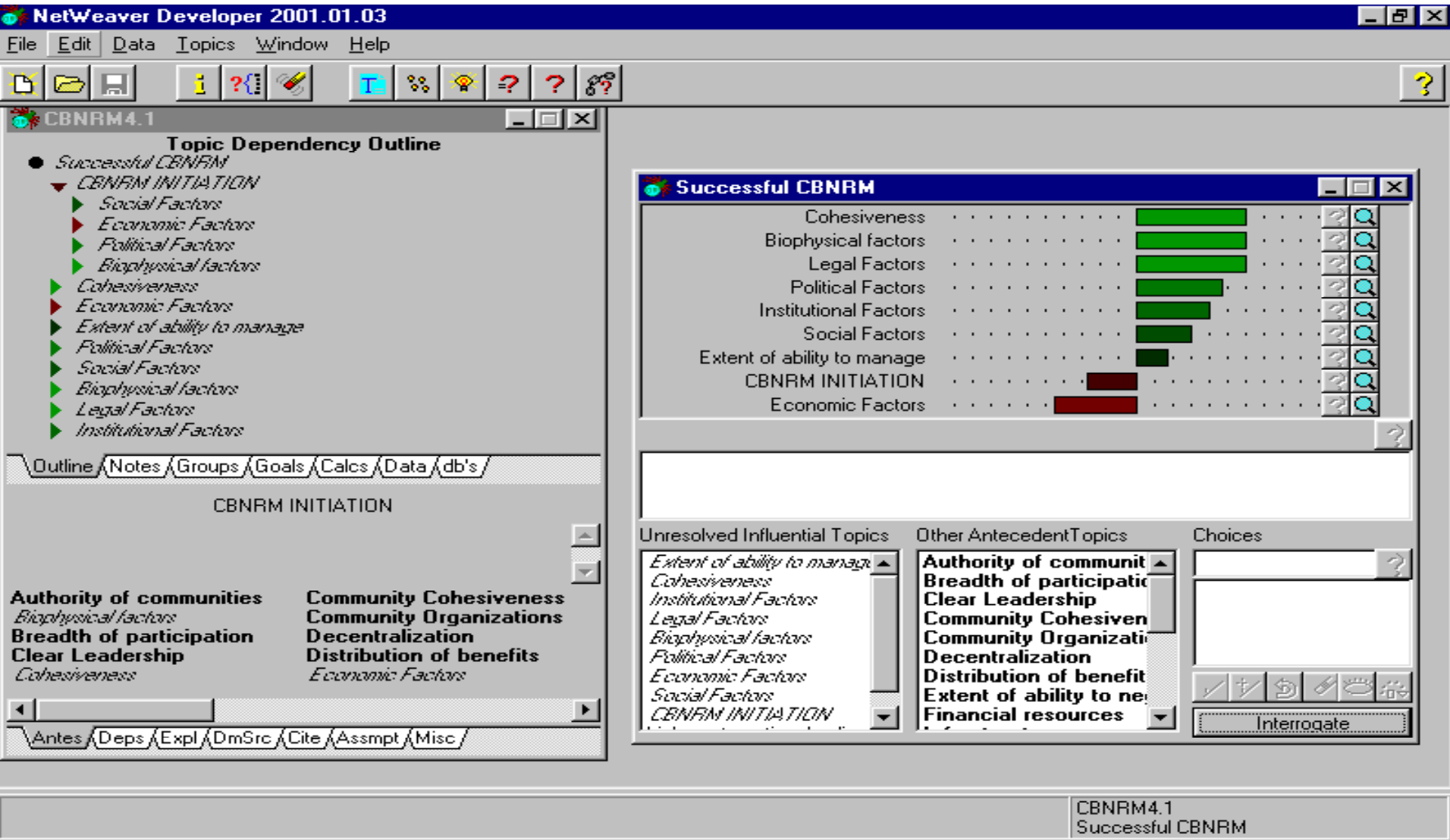
Array of Factors in NetWeaver™
CBNRM Initiation Model
After Development and Sensitivity Analysis



Dependency Networks and Data Links
For NetWeaver™ CBNRM Model Social Factors

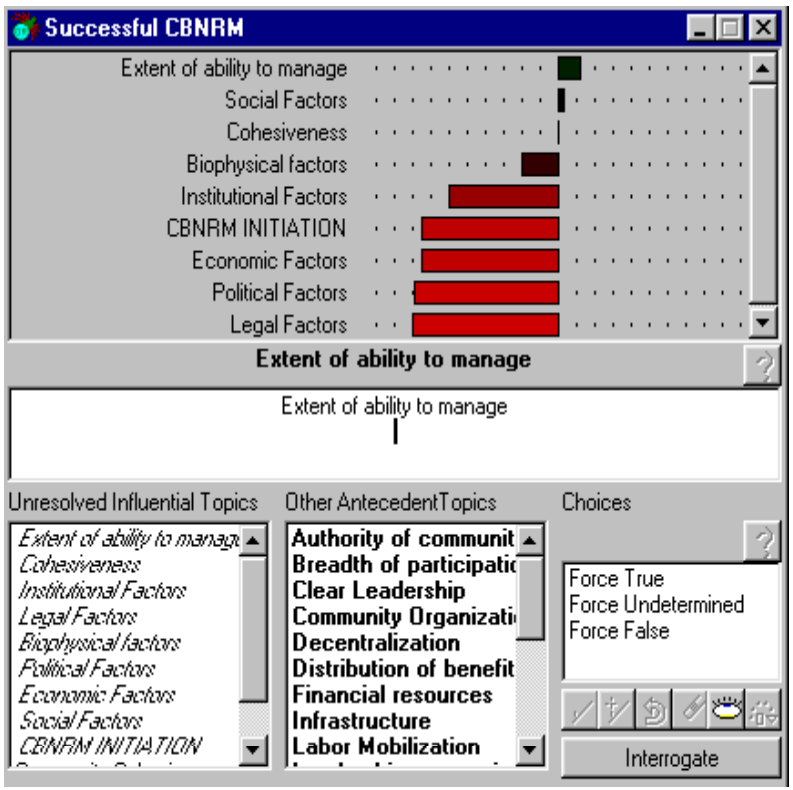


NetWeaver™
Topic Dependency Outline and Evaluation Window

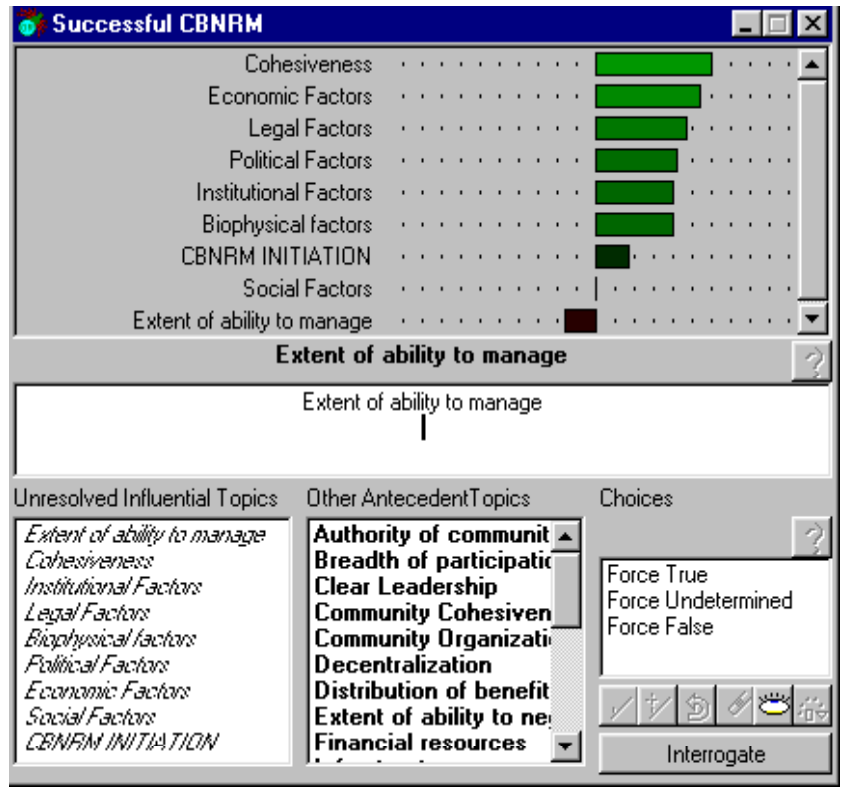


NetWeaver CBNRM Model Outputs

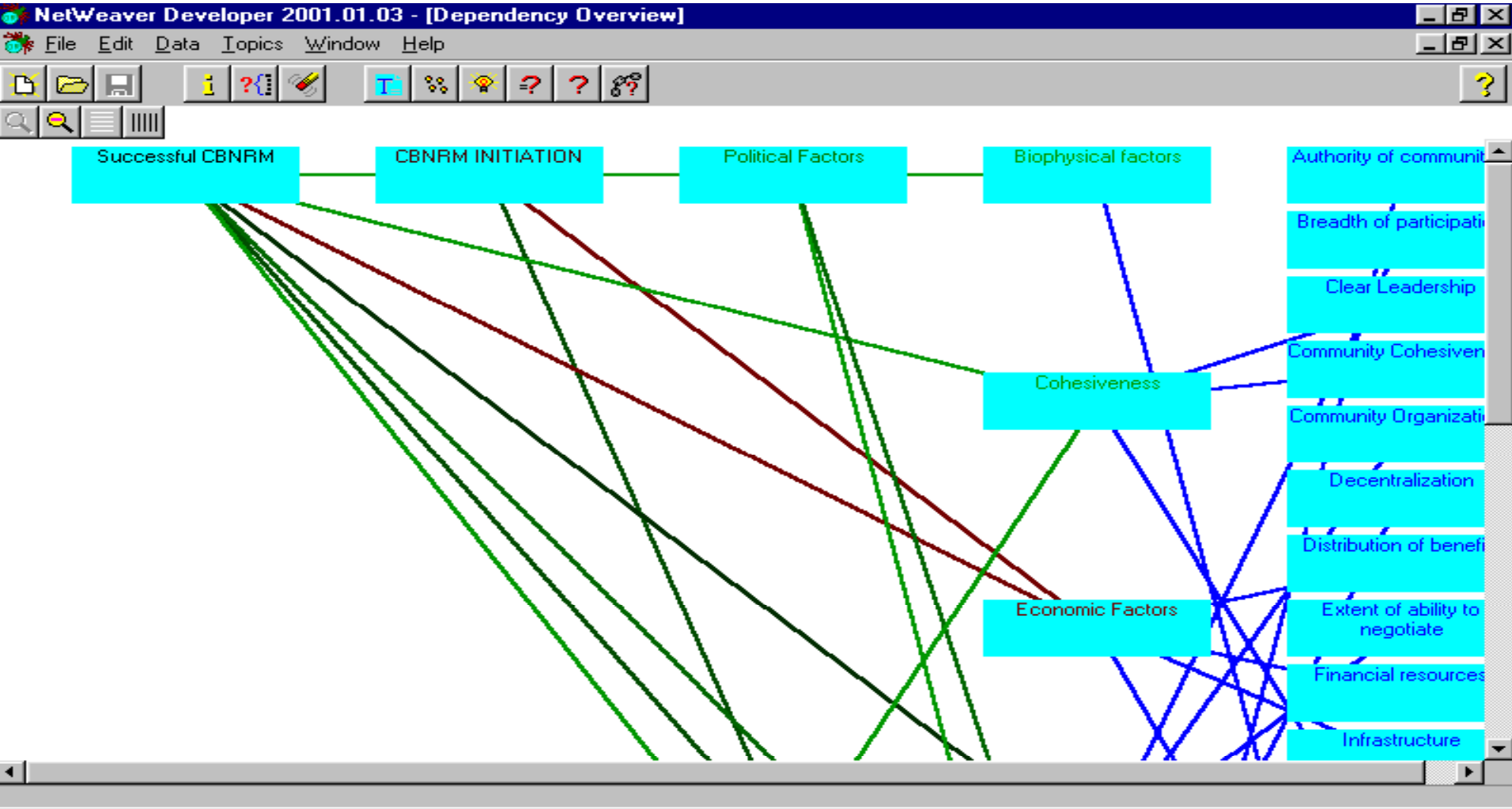
Output for Dataset 1



Output for Dataset 2



NetWeaver™ Dependency Overview Demonstrating Linkages Between Determinants and their Contribution to Achievement of Some Degree of CBNRM Success

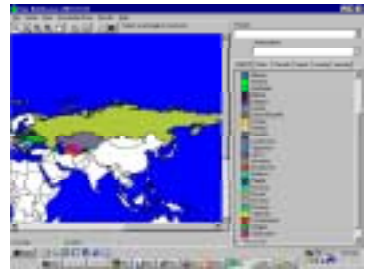


Other Potential Applications of NetWeaver™ and GeoNetWeaver™

-Reduction of impact from natural disasters
-Impact of AIDS on human resources for NRM
-Environmental trends analysis
-Ecosystem management
-Data needs assessment
-Forest certification
-Analysis of water quality for development permit process
-Results-oriented strategic planning
-Performance monitoring

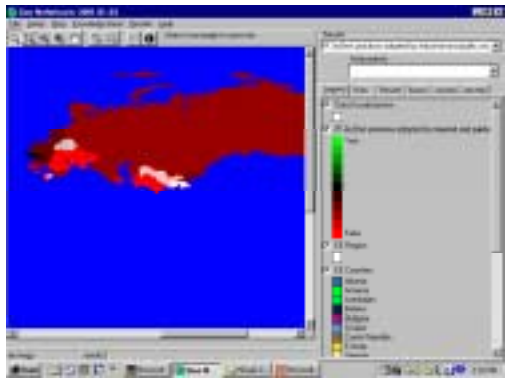
GeoNetWeaver™ :
An Application in Results-Oriented Planning and Monitoring

1



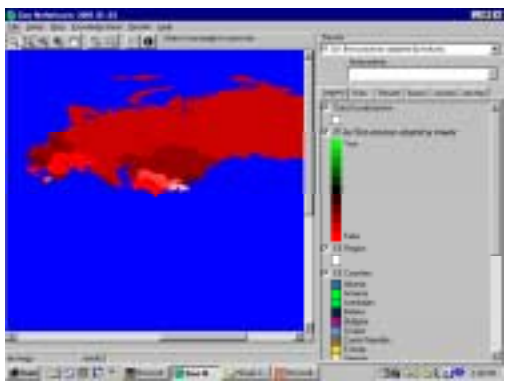
GeoNetWeaver™ View of Eastern Europe & Eurasia Region

2



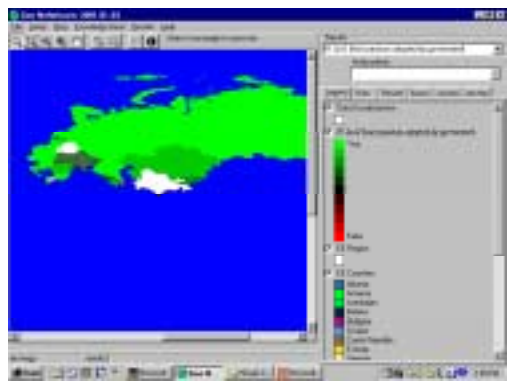
Results of GeoNetWeaver™ Analysis of Data by Country for IR3a (Adoption of Best Practices by Industry and Public Sector Combined)

3



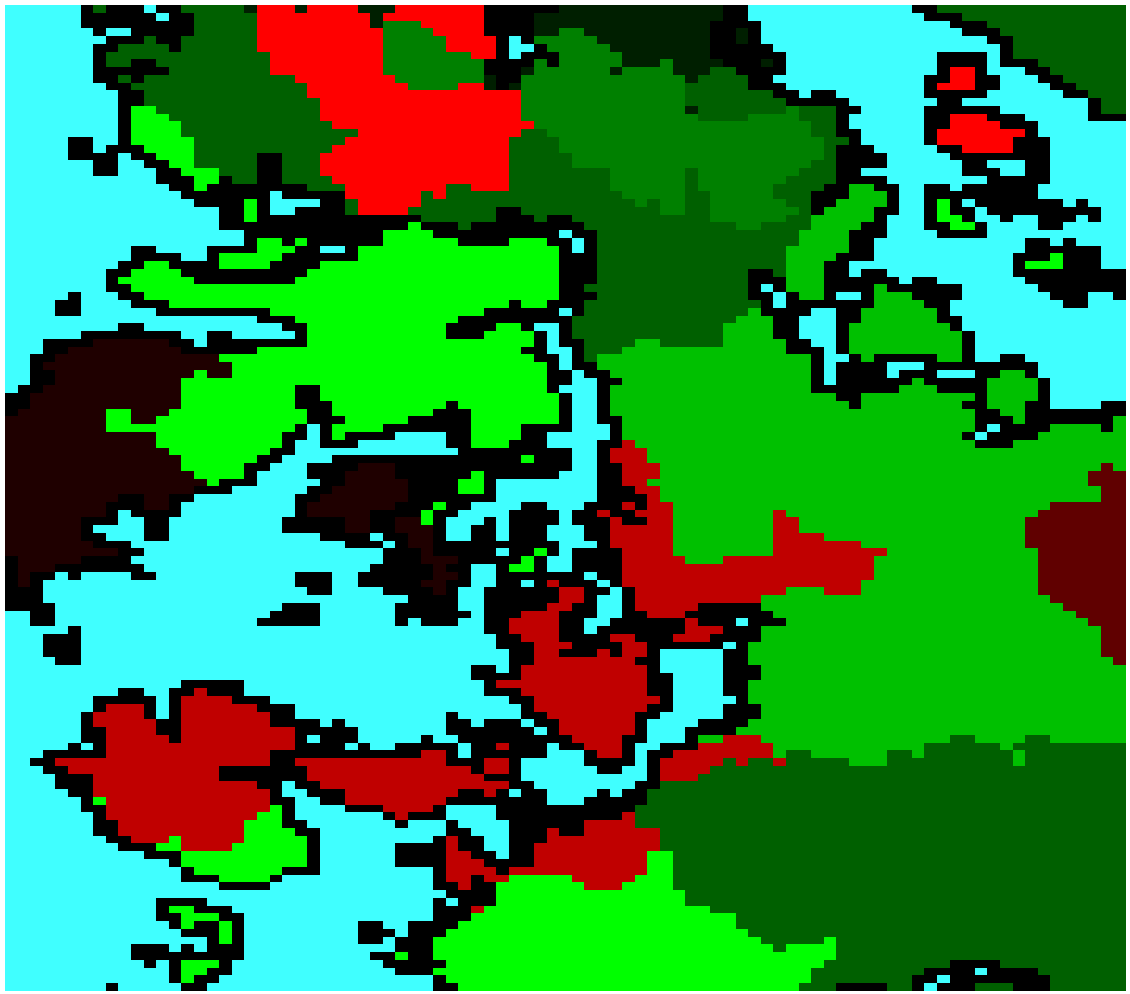
Results of GeoNetWeaver™ Analysis of Data by Country for IR3a for Industry

4



Results of GeoNetWeaver™ Analysis of Data by Country for IR3a for Public Sector

Potential Use of GeoNetWeaver for Forest Certification in the SE



for more information contact

THE HERON GROUP, LLC

www.herongroupllc.com