Fifth IFSA World Congress (1993), 1051-1053

APPLICATION OF FUZZY SET THEORY IN SAFEGUARDS

A. Fattah

International Atomic Energy Agency
Vienna, Austria.

Y. Nishiwaki

Institute for Medical Physics,
University of Vienna, Austria.

ABSTRACT

The International Atomic Energy Agency's Statute in Article III.A.5 allows it "to establish and administer safeguards designed to ensure that special fissionable and other materials, services, equipment, facilities and information made available by the Agency or at its request or under its supervision or control are not used in such a way as to further any military purpose; and to apply safeguards, at the request of the parties, to any bilateral or multilateral arrangement, or at the request of a State, to any of that State's activities in the field of atomic energy".

Safeguards are essentially a technical means of verifying the fulfilment of political obligations undertaken by States and given a legal force in international agreements relating to the peaceful uses of nuclear energy. The main political objectives are: to assure the international community that States are complying with their non-proliferation and other peaceful undertakings; and to deter
(a) the diversion of safeguarded nuclear materials to the production of nuclear explosives or for military purposes and
(b) the misuse of safeguarded facilities with the aim of producing unsafeguarded nuclear material.

It is clear that no international safeguards system can physically prevent diversion. The IAEA safeguards system is basically a verification measure designed to provide assurance in those cases in which diversion has not occurred. Verification is accomplished by two basic means: material accountancy and containment and surveillance measures. Nuclear material accountancy is the fundamental IAEA safeguards mechanism, while containment and surveillance serve as important complementary measures.

Material accountancy refers to a collection of measurements and other determinations which enable the State and the Agency to maintain a current picture of the location and movement of nuclear material into and out of material balance areas, i.e. areas where all material entering or leaving is measurable.

A containment measure is one that is designed by taking advantage of structural characteristics, such as containers, tanks or pipes, etc. to establish the physical integrity of an area or item by preventing the undetected movement of nuclear material or equipment.

Such measures involve the application of tamper-indicating or surveillance devices. Surveillance refers to both human and instrumental observation aimed at indicating the movement of nuclear material.

The verification process consists of three over-lapping elements:

(a) Provision by the State of information such as
- design information describing nuclear installations;
- accounting reports listing nuclear material inventories, receipts and shipments;
- documents amplifying and clarifying reports, as applicable;
- notification of international transfers of nuclear material.

(b) Collection by the IAEA of information through inspection activities such as
- verification of design information
- examination of records and reports
- measurement of nuclear material
- examination of containment and surveillance measures
- follow-up activities in case of unusual findings.

(c) Evaluation of the information provided by the State and of that collected by inspectors to determine the completeness, accuracy and validity of the information provided by the State and to resolve any anomalies and discrepancies.

To design an effective verification system, one must identify possible ways and means by which nuclear material could be diverted from peaceful uses, including means to conceal such diversions. These theoretical ways and means, which have become known as diversion strategies, are used as one of the basic inputs for the development of safeguards procedures, equipment and instrumentation.

For analysis of implementation strategy purposes, it is assumed that non-compliance cannot be excluded a priori and that consequently there is a low but non-zero probability that a diversion could be attempted in all safeguards situations. An important element of diversion strategies is the identification of various possible diversion paths; the amount, type and location of nuclear material involved, the physical route and conversion of the material that may take place, rate of removal and concealment methods, as appropriate.

With regard to the physical route and conversion of nuclear material the following main categories may be considered:

- unreported removal of nuclear material from an installation or during transit
- unreported introduction of nuclear material into an installation
- unreported transfer of nuclear material from one material balance area to another
- unreported production of nuclear material, e.g. enrichment of uranium or production of plutonium
- undeclared uses of the material within the installation.

With respect to the amount of nuclear material that might be diverted in a given time (the diversion rate), the continuum between the following two limiting cases is considered:

- one significant quantity or more in a short time, often known as abrupt diversion; and
- one significant quantity or more per year, for example, by accumulation of smaller amounts each time to add up to a significant quantity over a period of one year, often called protracted diversion.

Concealment methods may include:

- restriction of access of inspectors
- falsification of records, reports and other documents
- borrowing of nuclear material from other material balance areas

- replacement of nuclear material, e.g. use of dummy objects
- falsification of measurements or of their evaluation
- interference with IAEA installed equipment.

As a result of diversion and its concealment or other actions, anomalies will occur. All reasonable diversion routes, scenarios/strategies and concealment methods have to be taken into account in designing safeguards implementation strategies so as to provide sufficient opportunities for the IAEA to observe such anomalies.

The safeguards approach for each facility will make a different use of these procedures, equipment and instrumentation according to the various diversion strategies which could be applicable to that facility and according to the detection and inspection goals which are applied. Postulated pathways or sets of scenarios comprise those elements of diversion strategies which might be carried out at a facility or across a State's fuel cycle with declared or undeclared activities. All such factors, however, contain a degree of fuzziness that need a human judgment to make the ultimate conclusion that all material is being used for peaceful purposes.

Safeguards has been traditionally based on verification of declared material and facilities using material accountancy as a fundamental measure. The strength of material accountancy is based on the fact that it allows to detect any diversion independent of the diversion route taken. Material accountancy detects a diversion after it actually happened and thus is powerless to physically prevent it and can only deter by the risk of early detection any contemplation by State authorities to carry out a diversion.

Recently the IAEA has been faced with new challenges. To deal with these, various measures are being reconsidered to strengthen the safeguards system such as

- enhanced assessment of the completeness of the State's initial declaration of nuclear material and installations under its jurisdiction
- enhanced monitoring and analysis of open information that may indicate inconsistencies with the State's safeguards obligations.

Precise information vital for such enhanced assessments and analyses is normally not available or, if available, difficult and expensive collection of information would be necessary. Above all, realistic appraisal of truth needs sound human judgment.

References

[1] **INTERNATIONAL ATOMIC ENERGY AGENCY,** Treaty on the Non-Proliferation of Nuclear Weapons. INFCIRC/140, 23 April 1970.

[2] **INTERNATIONAL ATOMIC ENERGY AGENCY,** The Structure and Content of Agreements between the Agency and States Required in Connection with the Treaty on the Non-Proliferation of Nuclear Weapons. INFCIRC/153 (Corrected). Vienna, June 1972.

[3] **INTERNATIONAL ATOMIC ENERGY AGENCY,** The Agency's Safeguards System (1965, as provisionally extended in 1966 and 1968). INFCIRC/66/Rev.2. Vienna, September 1968.