INTERNATIONAL STANDARD

ISO 15704

First edition
2000-06-01

AMENDMENT 1
2005-08-15

Industrial automation systems — Requirements for enterprise-reference architectures and methodologies —

AMENDMENT 1: Additional views for user concerns

Systèmes d'automatisation industrielle — Prescriptions pour architectures de référence entreprise et méthodologies —

AMENDEMENT 1: Vues additionnelles pour les intérêts de l'usager

Reference number
ISO 15704:2000/Amd.1:2005(E)

Foreword

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Amendment 1 to International Standard ISO 15704:2000 was prepared by Technical Committee ISO/TC 184, *Industrial automation systems and integration*, Subcommittee SC 5, *Architecture, communications and integration frameworks*. In preparing this amendment, substantive contributions were received from groups involved with enterprise-reference architectures such as the Purdue Enterprise-Reference Architecture (PERA), the Graphes et Résultats et Activités Interreliés GRAI Integrated Methodology (GRAI GIM), the Computer Integrated Manufacturing Open System Architecture (CIMOSA), and the Generalised Enterprise-Reference Architecture and Methodology (GERAM).

Industrial automation systems — Requirements for enterprise-reference architectures and methodologies —

AMENDMENT 1: Additional views for user concerns

Page vi, Foreword

Replace the last paragraph with the following:

> "Annexes A, B, C, and D are informative. Annex A is based on version 1.6.2 of GERAM developed by the IFIP/IFAC Task Force on Architectures for Enterprise Integration who granted permission for its inclusion in ISO 15704. Annex B is based on the economic view found in A Stair-Like CIM System Architecture of Chen and Tseng. Annex C is based upon the decisional view found in CEN/TS14818 Technical Specification – Enterprise Integration – Decisional Reference Model."

Page 1, subclause 3.2

Replace (a) in the note with the following:

> "a) system architectures (sometimes referred to as "type 1" architectures) that deal with the design of a system, e.g. the computer control system part of an overall enterprise integration system;"

Page 5, subclause 4.2.6

Replace with the following:

> "Enterprise-reference architectures and methodologies shall exhibit the capability to represent any process and its constituent activities for the accomplishment of the management and control in support of the established mission of the enterprise according to the criteria established by enterprise management."

Page 6, subclause 4.2.10

Add the following paragraph after the last paragraph:

> "Model developers may generate additional views for particular user concerns, and these can then be used by any concerned stakeholder. Examples of additional views are found in annexes B and C."

Page 41, annex B

Add the following two annexes before the existing Annex B and renumber the existing Annex B and its subclauses accordingly.

Annex B
(informative)

Economic View in CIM system architecture

B.1 General

B.1.1 Introduction

For entrepreneurs and business managers, confidence in advanced CIM technology depends upon the realization of a return on investment projected from design phase activities of both new system implementations and system up-grades and re-organizations/integrations. Since both tangible and intangible benefits must be considered, evaluating the return is a difficult problem. An essential aspect of any mechanism to resolve the problem is the ability to evaluate different alternatives using models of existing and proposed system architectures in a manner that connects functionality with economic consequence so that design trade-off decisions are possible. In particular, the evaluation of intangible benefits is often a barrier to Computer Integrated Manufacturing investments.

An Economic View presents model content relative to economic decisions. It draws upon existing model content and established analytical methods to inform decision makers. The view is most critical early in the life cycle when the majority of economic commitments are encountered and late in the life cycle when economic performance is measured.

B.1.2 Support for enterprise managers

As guidance for enterprise managers, the Economic View can help them to:

a) predict the influences of system integration on the enterprise,

b) evaluate necessary investment and possible benefits,

c) make decisions and improve their correctness, and

d) monitor the implementation process and application of the integrated system.

B.1.3 Support for enterprise model developers and analyzers

As guidance for model developers and analyzers, the Economic View helps them to:

a) describe the economic elements,

b) understand relationships between these elements and other components in an integrated system,

c) describe economic relationships among enterprise strategic targets, the framework of the integrated system and its components, and

d) identify economic benefits of enterprise re-organization.

B.1.4 Support for system developers

As guidance for the system developers, the Economic View provides:

a) methods to evaluate economic consequences of system function modifications during the system development, and

b) scoping of software tool use for economic modeling and analysis.

B.2 Framework for Economic View

In system implementation/integration projects, the goals and corresponding demands of the project target are reflected in the demands of the economic characteristics. Their economic implications/influences on the system are realized through the integration strategy and the technology project. The Economic View establishes the relations between the economic target and the engineering project. It describes economic elements, influence factors and scalar indices manifested in the integrated system and their relationships that allow the determination of their impacts on the economic targets in the system integration project. These indices, factors, and elements are constructs and their properties taken from or derived from the four mandatory model-content views (4.2.10)

In an integrated system, the Economic View consists of a grouping of models, which is used to describe economic components and their relationships. Many methods, e.g., graphical, mathematical, and even descriptive ones, may describe economic components. In order to improve the compatibility and assure the successful operation of an enterprise, a three-layer framework is constructed, expressed in graphic form, based on enterprise modeling methods and reference models in the general enterprise reference architecture, as shown in Figure B1.

The three layers in the Framework for Economic View (Indices, Factors, Elements) possess different economic attributes and the relationships among layers have different attributes as well. The framework establishes the relationships between layers of detail from the top level strategic targets of an enterprise to the bottom basic economic elements with intervening indices and factors. To correctly establish the relationships among different layers, both clustering and classification methods should be used to gather information from the generic and partial model pool for the applicable life cycle phases and then classify the information to establish the particular trees and relationships.

Early in the life-cycle, economic targets (ET) and constraints are established, e.g., return on investment, and pricing levels. Relative to this domain identification and concept definition, sets of economic indices (I_j) bearing on the targets and constraints are arranged and analytic methods are chosen with increasing levels of detail exposed as the life cycle progresses. At the factors layer, process related cost factors are derived from the decomposition of process models into activities (f_P). At this layer other economic factors result from the analytical breakdown of expected value that can be both tangible and intangible (f_A). All of the indices have both tangible and intangible factors. Even the most tangible indices, cost (I_C) and time (I_T) may have intangible factor influences that need to be taken into consideration. The explicit intangible factors, service (I_S) and environment (I_E) may have tangible factors as well, e.g., response time, pollution rate, etc. Tangible factors have diverse forms and representation. They can be expressed in mathematical equations (f_E), matrices, tables (f_T), boxes in graphical models, etc. In Figure B.1, the design phase is shown with greater elaboration using a tree of decomposed indices, process factors (f_P) depicted as a process model fragment, analytical factors (f_A) depicted as hierarchy models, equation factors (f_E) depicted as a formula, and table factors (f_T) depicted as a data table.

For factors, the element layer identifies the basic economic elements that comprise the variables in the mathematical equations (ϵ_E), the entries in the matrices and tables (ϵ_T), the activities (such as an activity box, e.g., in the lowest level IDEF3 model, (ϵ_A)), etc., from which the factor cost or value are derived. These elements are usually simple attribute values characterized as indivisible, and can be used to measure, monitor, or control the related factors. In general the elements are properties of resources used to value and cost an activity.

Economic indices, factors, and elements can be of generic types collected as a pool of constructs for use at the various layers. These generic types can be formed into partial models of indices and factors to be used as an aide for populating a particular economic view through specialization.

Analysis methods vary by layer with, for example, tree hierarchy analysis techniques appropriate at the Indices layer, and process structure model simulation, hierarchy analysis, physics formulas, fit and interpolation methods at the Factor layer. These analysis methods collect data and support the decision optimization of the enterprise. Optimization results can be imposed on attributes to realize the enterprise strategy and improve its competitive ability. Two iterations of optimization and control exist - the target decomposition from the top down at Requirements, followed by system analysis from the bottom up at Design occurs early in the life cycle and then the system implementation from the top down at Implementation and the system monitor and control from the bottom up at Operation occurs later in the life cycle. The first iteration results in the roll-up of economic valuations for comparison against the targets and constraints. The second iteration provides measures of economic performance.

Such methods can assure the realization of the enterprise target, the fundamental information collection and analysis, the rationalized target fulfillment and the system monitoring. Implementation of the framework should be supported by correct methodology, rich engineering practices and advanced theories and methods of system integration. Initiatives in concurrent engineering, cell technologies, and total quality management may be coupled with capital and labor investment for economic benefit.

The analysis and evaluation of different implementation alternatives of CIMS can be performed using the Economic View. The selection of the best alternative from many opportunities to implement system integration and the improvement of the enterprise competency is achieved as a result of specific modeling methods.

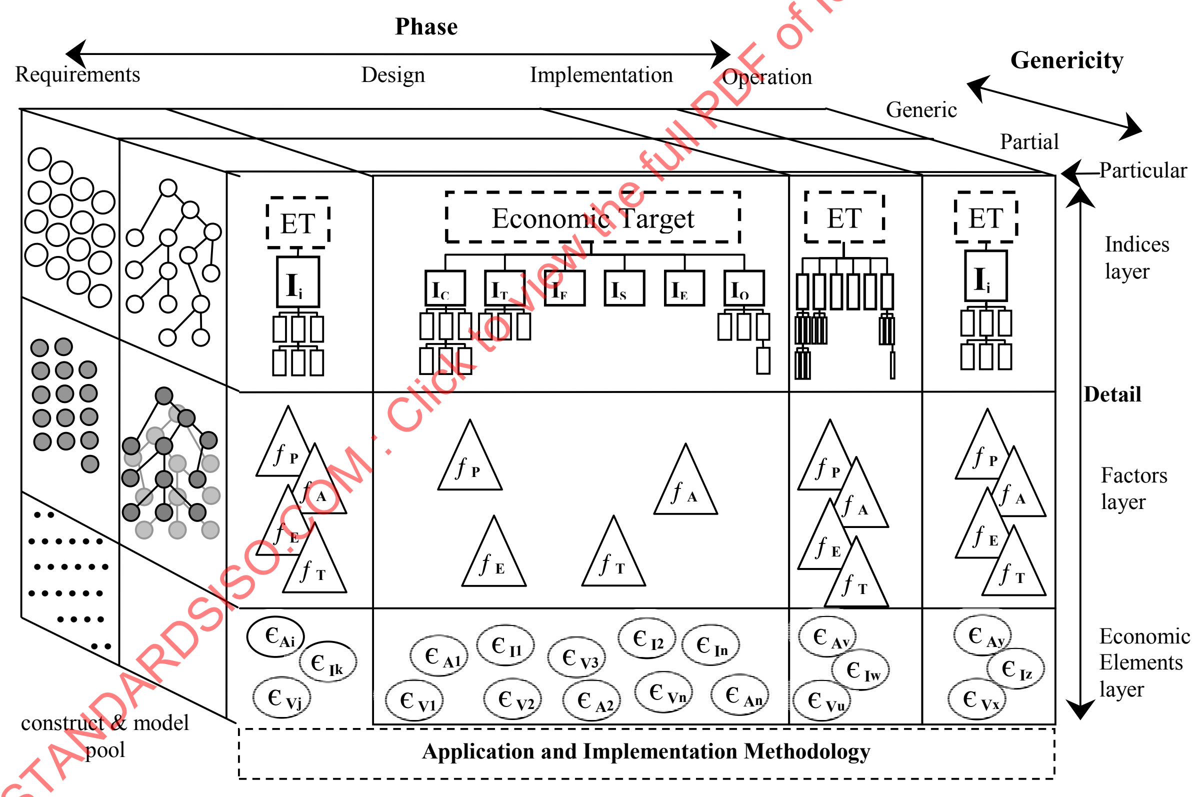
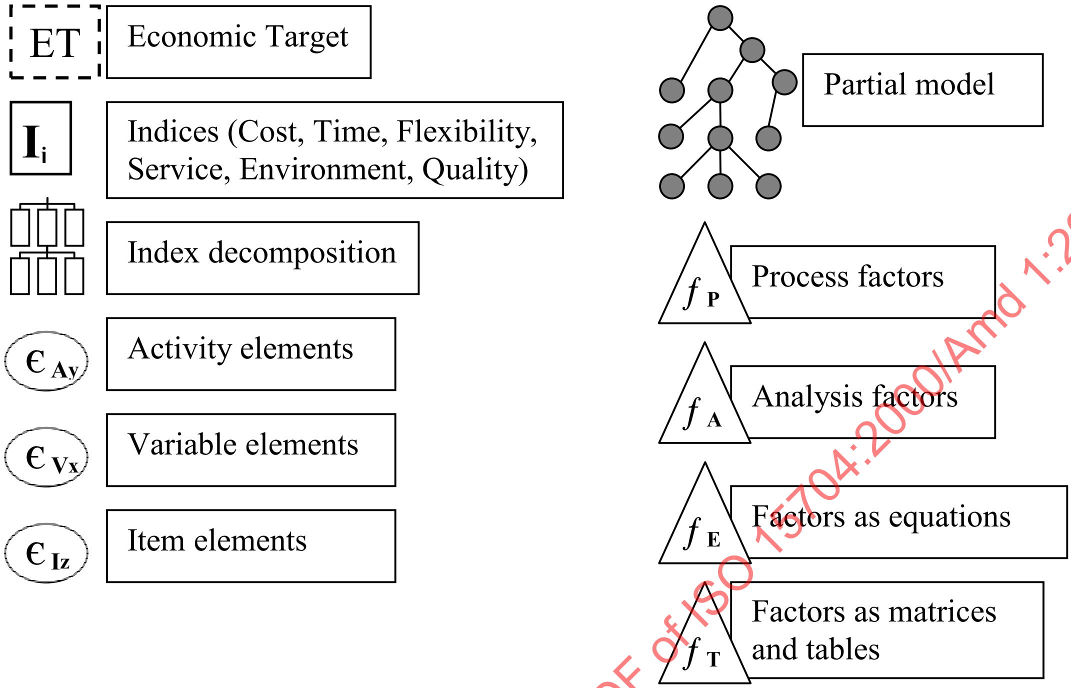


Figure B.1 — Framework for Economic View

Table B.1 — Icons for Figure B.1



B.3 Candidate modelling methods

B.3.1 Introduction

Two methods used at the Factor layer, depicted in Figure B.1 as f_A and as hierarchy models, are presented below and followed by illustrative examples.

B.3.2 Activity Based Costing

Activity Based Costing (ABC) is a method to measure the cost and performance of an organization based on the activities, which the organization uses in producing its output. ABC differs from traditional cost accounting techniques in that it accounts for all "fixed" and indirect costs as variables, without allocating costs based upon a customer's unit volume, total days in production or percentage of indirect costs. Information gathered through ABC should provide a cross-functional, integrated view of your organization, including its activities and its business processes. [1]

B.3.3 Analytic Hierarchy Process/Analytic Network Process

The Analytic Hierarchy Process (AHP) is a decision making process to help set priorities and make decisions when both qualitative and quantitative aspects of a decision need to be considered. By reducing complex decisions to a series of one-to-one comparisons, then synthesizing the results, AHP helps decision makers arrive at optimal decisions and provides a clear rationale for those decisions. The AHP engages decision makers in breaking down a decision making procedure into smaller parts, proceeding from the goal to criteria and sub-criteria from the Indices layer, down to the alternative courses of action. Decision makers then make simple pair wise comparison judgments throughout the hierarchy to arrive at overall priorities for the alternatives. The decision problem may involve social, political, technical, and economic factors. The AHP method helps people cope with the intuitive, the rational and the irrational factors, and with risk and uncertainty in complex settings. It can be used to: predict likely outcomes, plan projected and desired future, facilitate group decision making, exercise control over changes in the decision making system, allocate resources, select alternatives, do cost/benefit comparisons, evaluate employees and allocate wage increases. [2]

The Analytic Network Process (ANP) is a general theory of relative measurement for deriving composite priority ratio scales from individual ratio scales that represent relative measurements of the influence of attributes that interact with respect to control criteria. Through its super matrix, whose attributes are themselves matrices of column priorities, the ANP captures the outcome of dependence and feedback within and between clusters of attributes. The Analytic Hierarchy Process (AHP), with its dependence assumptions on clusters and attributes, is a special case of the ANP. ANP augments the linear structures used in traditional approaches and their inability to deal with feedback in order to choose alternatives. ANP offers decision making according to attributes and criteria as well as according to both positive and negative consequences.[3]

B.4 Applying Economic View in model development

B.4.1 Introduction

Using the candidate methods of B.3, a subset of an Economic View as an example is presented below. The models chosen help decision makers align costs and value with targets and constraints.

B.4.2 ABC Method example

In order to accurately assess CIM technology benefits to enterprises, a costing technique that considers not only production but also other processes is required. For this example the modeling formalism is based on the IDEF0 method.[4] Since both ABC and IDEF0 focus on functional activities, the IDEF0 model is extended to include activity based costing data. In this way we assure that no activity cost assignment will be missed during the integration with an IDEF0 model. Here, a separate economic model that corresponds to the IDEF0 model of function view is constructed. There are four attributes in each model block: 1) node number, 2) activity name, 3) cost driver and 4) cost value. The first two attributes are taken directly from an IDEF0 model, whereas the latter two are to be defined by designers. As shown in Figure B2., the cost model forms a hierarchy exactly like the IDEF0 model. Sub-processes are defined down to Element layer activities that are the most basic.

Guidelines for constructing an ABC economic model include:

a) No attribute can be left empty;

b) Cost value of a parent process must be the sum of the cost values of all its lower-level sub-processes or activities;

c) If there is a cost for coordinating activities of the same level, coordination should be modeled as an activity of that level;

d) The model can be decomposed as a hierarchy equivalent to the IDEF0 hierarchy;

e) Assignment of cost values should be done in a bottom up manner, so that higher-level activity cost values can be consolidated and assigned accordingly.

For example, as shown in Figure B.2, the cost drivers of the process ‘Delivery of Part As’, ‘Preparation of raw material’, ‘Production of Part As’, ‘Purchasing material’, ‘Work order control for part delivery’, ‘Preparation of NC program’, ‘Machine set-up’, and ‘Machining’, are defined. Then we assign cost values for ‘Preparation of NC program’, ‘Machine set-up’ and ‘Machining’ (basic economic Elements). Hence, the cost value for ‘Production of Part As’ is calculated by summing the A2 cost values (A21 + A22 + A23). Similarly, the cost values for ‘Preparation of raw material’, ‘Purchasing material’, and ‘Work order control for part delivery’, are assigned. Finally the cost for ‘Delivery of Part As’ is determined. In order to deliver a product, processes like production planning and shipping are necessary and thus the costs for these processes are added to determine the total cost of a product. Note that the ABC modeling method can be applied to the existing processes as well as estimating costs for new systems. The objective is to accurately capture or estimate the project costs.

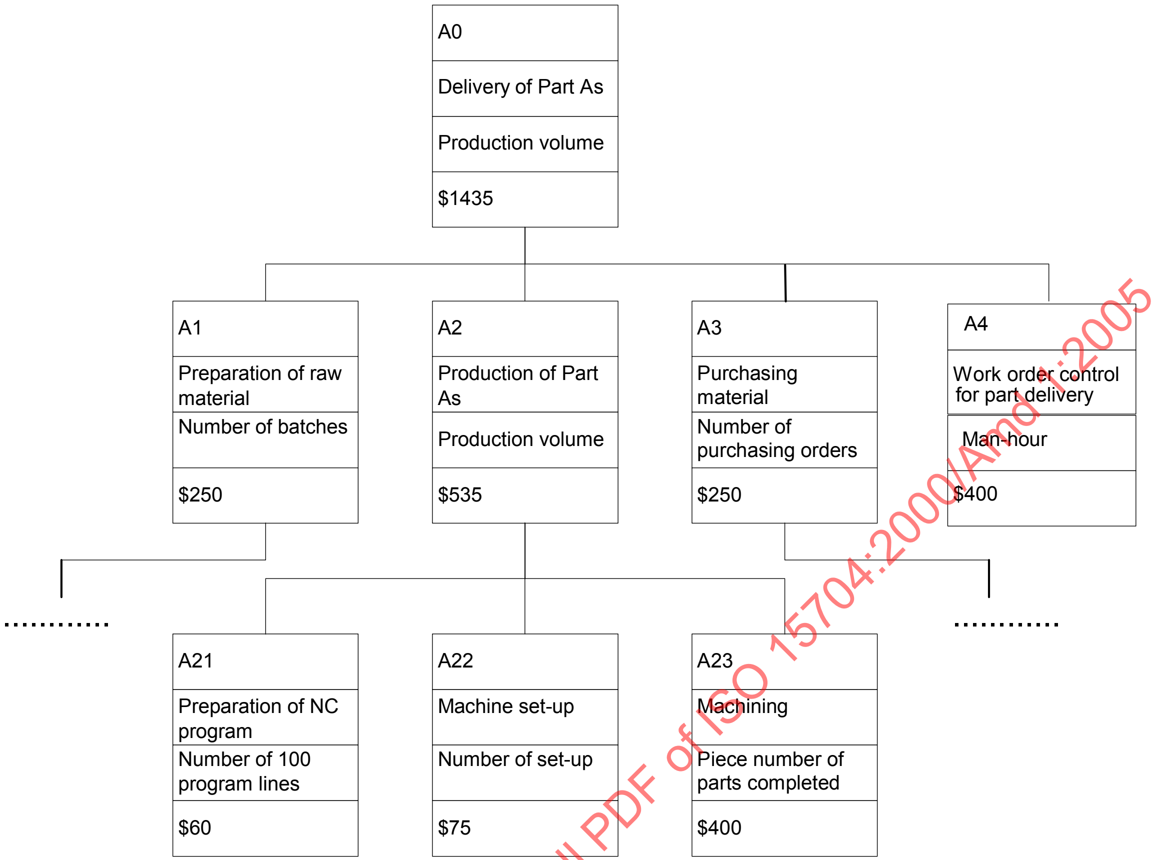


Figure B.2 — Example of a cost hierarchy

B.4.3 AHP Method example

Since investing in CIM often is not for the sake of the technology itself, it is especially important that the resulting business and manufacturing processes meet the target performance. Operational measures of performance should be derived from company goals that align with corporate strategies at Indices layer. The questions to resolve are: 1) whether the technology investment can effectively bring the business to the target, and 2) is the investment economically sound. The Activity Based Costing technique discussed in the above section (B.3.3) addresses the tangible aspect and deals with the second question. The first question is addressed using the Analytic Hierarchy Process (AHP) method at the Factors layer.

For example, a manufacturing company is launching a technology advancement project in order to keep company growth on target. Funds are reserved for the first stage of project effort. Due to a budget limit for the first phase, a team of managers, analysts and engineers are asked to make an investment proposal. The AHP method is employed by the team to decide which area of the project will receive initial funds allocation. A hierarchy of the advancement investment problem is constructed as in Figure B.3.

During the analysis, it is observed that product cost, production lead time, product quality and customer service contribute differently to market share and profitability. Similarly, increasing market share and enhancing profitability are contributing differently to the goal of company growth. The Analytical Hierarchy Process method weights the contributions of alternatives to the goal.

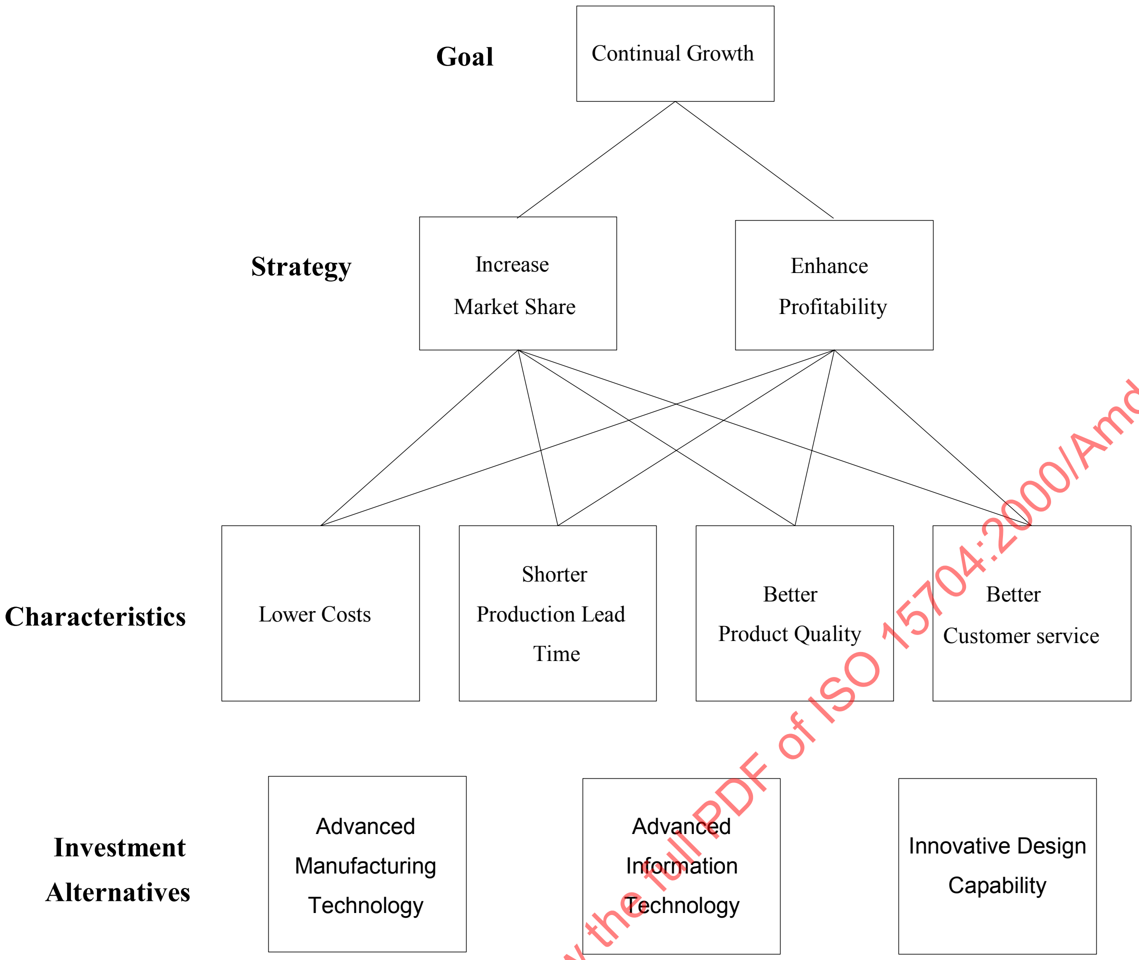


Figure B.3 — The hierarchy of advanced investment

B.4.4 Using example method results

In terms of cost and benefit analysis, benefit indices are defined based upon AHP priorities. The cost indices are defined using the ABC method. First, cost components of investment in manufacturing technology, information technology and design technology are determined. These cost components should include the process costs after the particular technology is invested as well. To reduce the possible bias caused by high capital costs, the capital cost may be left to the return on investment calculation. After the IDEF0 hierarchies and the cost hierarchies are built, the total cost is computed.

B.5 Glossary of references for Economic View

[1] Chen Yuliu, Tseng M M, Yien J. Economic view of CIM system architecture. Production Planning and Control, 1998, 9(3):241-249

[2] Saaty, T. L., Multicriteria Decision Making: The Analytical Hierarchy Processes, (McGraw-Hill), 1980.

[3] Saaty, R. W., Decision Making in Complex Environments, (Super Decisions),2003.

[4] National Institute for Standards and Technology, Standard for Functional Modeling – IDEF0, FIPS Publication 183, 1993.

Annex C
(informative)

Decision View of an enterprise model

C.1 Introduction

An enterprise is organised by functions and levels of responsibility. Decisions are made within multiple functions and multiple levels. The decision view is intended to support integration from a decision-making viewpoint. Decisions made within various functions shall be consistent in the sense that they shall contribute to achieving the global objectives of the enterprise. This also means that the time horizons in which various decisions are made are coordinated. In the domain of production management and control, to get the correct raw material/product at the correct time, on the correct machine and processed by the correct person implies that decisions are made in multiple time horizons.

The decision view described in this annex identifies production planning and control decisions and the relationships between them. These decisions are made using content from information and resource views under responsibility established in the organisation view.

The decision view is concerned with the description of an enterprise decision-making structure which provides for identification of decision topics, their categories, criteria and dependencies. This annex presents basic concepts relating to the decision view and focusing on the Production Management domain.

The decision view defines a generic integrated decision system structure in terms of a set of decision centres and decision links. It is a common structure for integrated decision-making in the domain of production planning and control. It serves as a basis to elaborate the decision model of a particular system.

The decision view is intended for those who are

a) decision-makers responsible of production management and control,

b) Involved in performing daily production planning and control activities,

c) Involved in designing production planning and control systems,

d) Involved in developing production planning and control software (i.e. MRPII, ERP, etc.), or

e) Involved in enterprise engineering and integration projects in general.

C.2 Decision View concepts

C.2.1 "Decision"

The term “decision” relates to “those activities or processes that are concerned with making choices”; the decision itself is “the result of choosing between different courses of action”. The activity of making a decision consists of choosing from amongst a set of known variables; the variable which best meets the objective, within the constraints.

C.2.2 Functional decision categories

Decision-making activities are classified into functional categories depending on the things they handle [Products (P), Resources (R) and Time (T)]. Combinations of these things lead to a categorization as follows (also see Figure C.1):

a) “manage products” (e.g. finished goods, sub-assemblies, parts and raw materials). These decisions are concerned with the management of products in time, (P ∩ T). Major decisions of this category are concerned with what, when and in which quantity those products are to be procured and which levels of inventory are appropriate;

b) “manage resources” (e.g. information technology and manufacturing technology resources as well as humans). These decisions are concerned with the management of resources in time, (R ∩ T). Major decisions of this category are concerned with the resource capacity/capability management;

c) “plan production” (e.g. master schedule, shop floor scheduling, etc.). These decisions are concerned with production planning that synchronizes the flow of products through resources in time, (P ∩ R ∩ T).

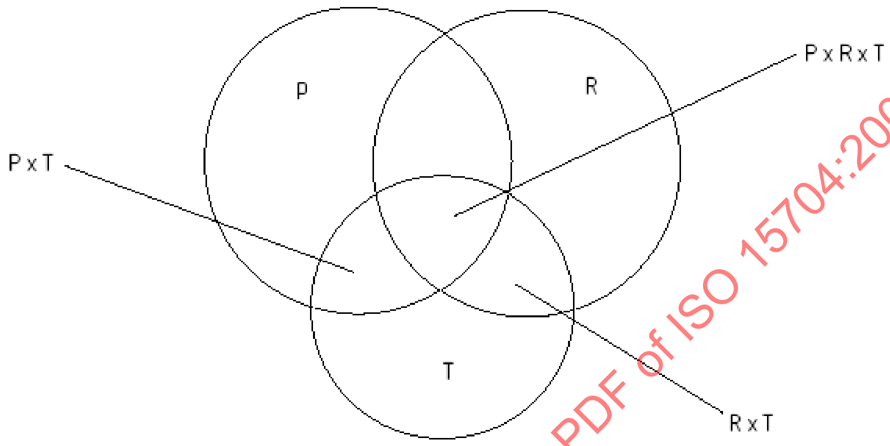


Figure C.1 — Three basic decision-making domains

C.2.3 Time decision categories

Decisions are classified into three general time categories:

a) Long-term and strategic in scope — these are long-term decisions that are concerned with the definition of objectives consistent with the global objectives of the enterprise;

b) Medium-term and tactical in scope —. these are medium-term decisions that deal with the implementation of means (both human and machine resources) to meet the strategic objectives;

c) Short-term and operational in scope —. these are short-term decisions associated with planning and execution of actions, using the means defined at the medium-term.

C.2.4 Specific time decision concepts

C.2.4.1 Horizon

A horizon is the part of the future taken into account by a decision, i.e. the horizon is six months when a decision is taken on a time interval of six months. The concept of horizon is closely related to the concept of planning. Thus the concept of horizon is also very close to the notion of time category (long-term, short-term, etc.) but is more precise. For example, in industrial production systems, a horizon gets quantified in relation to the customer order lead-time, the material requirements cycle times and the manufacturing cycle.

C.2.4.2 Period

The concept of period is closely related to the concept of control and adjustment. When a decision, based upon an objective, has been made to carry out some activity or activities during a subsequent horizon, the execution of these activities needs to be monitored. The intermediate results need to be measured with respect to the objective before this activity is completely finished and the horizon has terminated. If the measurements show that there is a deviation with respect to the reference objective, adjustments should be made. A period is the time that passes between a decision and when this decision shall be re-evaluated.

EXAMPLE A three-month plan may be re-evaluated and decided upon every two weeks, e.g. the horizon is three months and the period is two weeks.

The concept of period allows a manager to take system changes into account. These changes can come from the internal behaviour of the system (for example disturbances or machine breakdowns) and from outside (for example new customer orders arrive or problems arise related to providers).

C.2.5 Decision level

Decision level is an abstract concept that represents a decision-making hierarchy. It is defined by a pair of values indicating a horizon and period, (H,P). At a given decision level, all decisions made will have the same pair of values for horizon and period.

A particular decision level may be mapped to one of the three basic time categories (long-term, medium-term, and short-term). Each of the three basic levels may be decomposed on sub-levels. For example, in some companies, the long-term level may have two sub-levels with decisions dealing respectively with manufacturing strategies and long-term production planning. (see C.4.)

C.2.6 Decision centre

Decision centre is an abstract concept that represents the intersection of a decision level and a functional decision category of the domain. Decision centres are mapped onto an enterprise organization to identifying the people responsible for making various decisions. A decision centre is defined as the set of decisions made at one decision level and belonging to one functional category. Decision centres are the conceptual locations where decisions are made about the various objectives and goals that the system should reach and about the means available to operate in accordance with these objectives and goals. To manage a system, many decision centres operate concurrently, each with its own dynamics reflecting the various time-scales and dynamic requirements that management decisions need to address.

C.2.7 Decision frame

C.2.7.1 Decision frame content

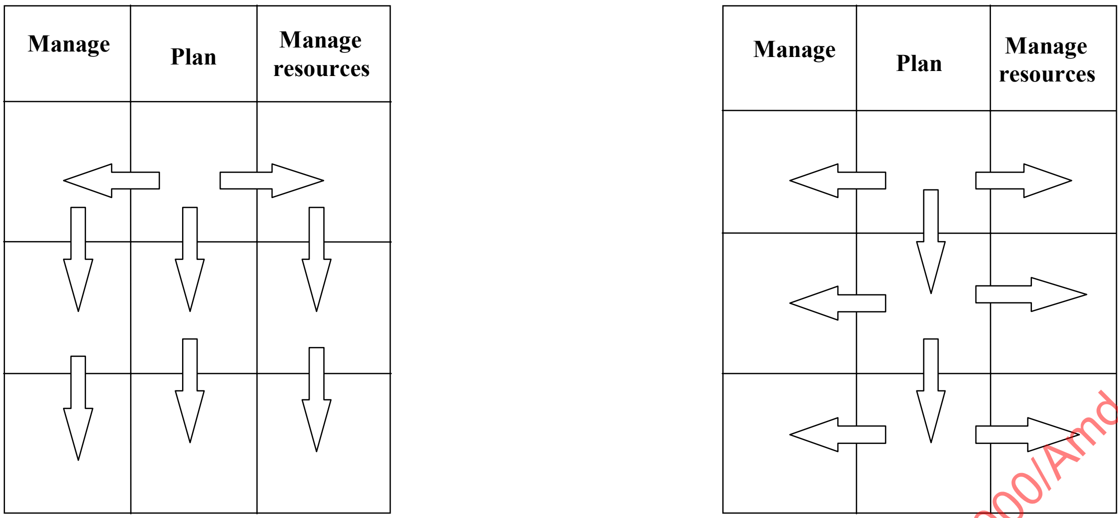
A decision frame is composed of the information content transmitted between decision centres that describes a set of items constraining the degrees of freedom for decision-making (see Figure C.2). This frame shall not be modified by a decision made in the decision centre receiving the frame. To avoid conflicts, a decision centre should be under the influence of only one decision frame.

The main items influencing decision-making are:

a) the decision objective or set of objectives that the decision has to meet;

b) the decision variables that enable the decision-maker to know the scope of available actions and their constraints;

c) the decision criteria that guide the choice in decision-making.



Coordinating structure **Synchronizing structure**

Figure C.2 — Styles of decision links

The items that make up the frames of decision-making are primarily determined by the hierarchy of the decision system. These items are decomposed in a consistent way by descending through the hierarchy of the system. Hence, through the decision frame, a decision centre transmits to another decision centre the objectives, the decision variables, the constraints and criteria that the latter should take into account when making decisions. This transmission is conducted as a dialogue referred to as a decision link.

There exist two basic frame structures defined by different styles of dialogue: coordinating and synchronizing as shown in Figure C.2. The coordinating structure emphasizes the coordination between various decision levels, while the synchronizing structure emphasizes the synchronization between various functional decision categories. The choice of structure depends on the management style of the enterprise and the situation for which the grid is being applied.

C.2.7.2 Decision objective

Objectives indicate performance targets. These performance targets can be the production costs, the delivery lead-time, or the level of quality, for example. Objectives are needed at every decision centre each time a decision is made. Global objectives refer to the entire production system and, according to the principle of coordination, are consistently detailed to give local objectives to all decision centres.

C.2.7.3 Decision variable

Decision variables are the items upon which a decision centre can make decisions that allow it to reach its objectives.

EXAMPLE For scheduling workers' working hours, a decision variable can be "the number of extra work hours", e.g. the decision frame of scheduling declares that scheduling decisions may decide upon the value of extra working hours in order to reach the objective of scheduling.

A decision centre may act upon one or more decision variables through determining their respective values. In other words, decisions are made in a decision space. The dimensionality of a decision space is determined by the number of decision variables.

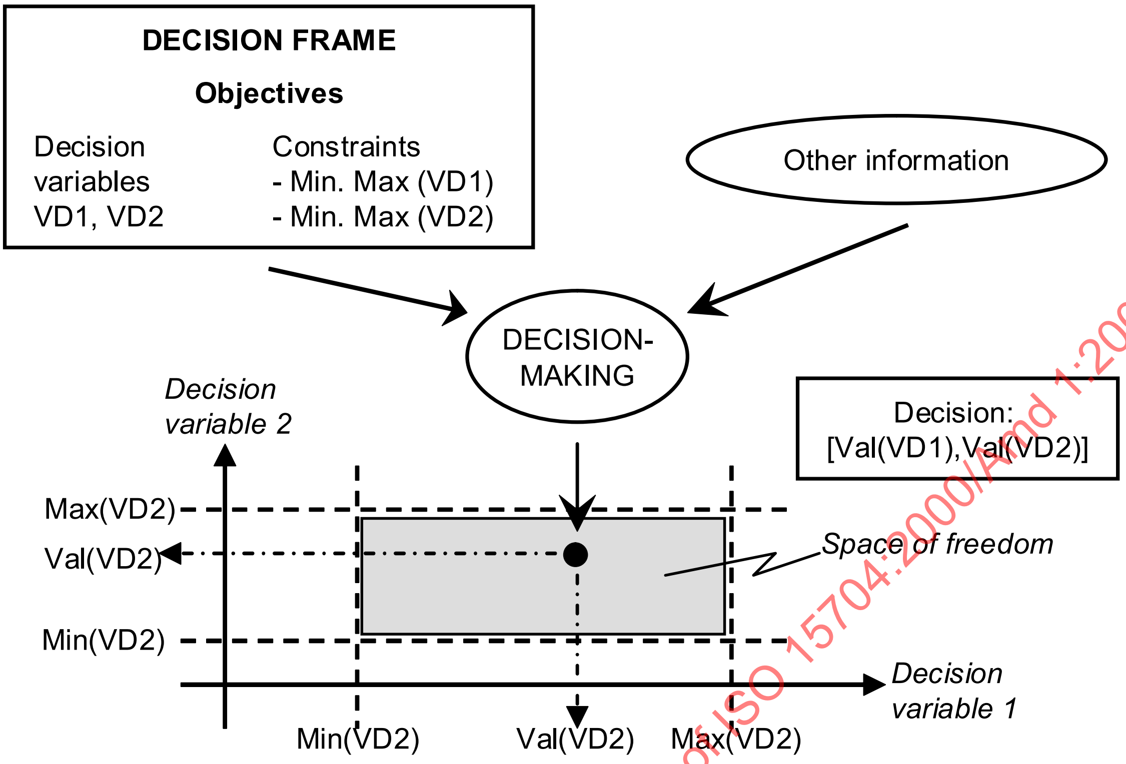


Figure C.3 — Decision space within a decision centre

C.2.7.4 Decision constraint

Constraints are the limitations on possible values of variables. Decision constraints limit the freedom of a decision centre to select any arbitrary value for its decision variables.

C.2.8 Performance indicator

A performance indicator is an aggregated piece of information that provides a measure allowing the comparison of the system's performance to the system's objectives. A performance indicator is defined by its name, a value domain and a procedure for determining its value.

Performance indicators should be consistent with objectives because it is necessary to compare performance targets (objectives) and performance attainment (indicators). Performance indicators should also be consistent with decision variables because those variables will have an effect on the performance monitored (controllability). The main issue is to ensure internal consistency within a decision centre in terms of the consistency triplet presented (see Figure C.4). This consistency is ensured if the performance indicators allow verification of the achievement of the objective and are influenced by actions on decision variables.