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Automation systems and integration — Evaluating energy efficiency and other factors of manufacturing systems that influence the environment —

Part 1: Overview and general principles

Systèmes d'automatisation et intégration — Évaluation de l'efficacité énergétique et autres facteurs de fabrication des systèmes qui influencent l'environnement —

Partie 1: Aperçu et principes généraux

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Foreword

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The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2. www.iso.org/directives

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The committee responsible for this document is ISO/TC 184, *Automation systems and integration*, Subcommittee SC 5, *Interoperability, integration, and architectures for enterprise systems and automation applications*.

ISO 20140 consists of the following parts, under the general title *Automation systems and integration — Evaluating energy efficiency and other factors of manufacturing systems that influence the environment:*

— *Part 1: Overview and general principles*

The following parts are under preparation:

— *Part 2: Environmental index evaluation process*

— *Part 3: Environmental influence aggregation process*

— *Part 4: Allocation/charge process of indirect influence/construction, reconfiguration and retirement (CRR) influence*

— *Part 5: Environmental influence evaluation data*

Introduction

This part of ISO 20140 establishes an overview and general principles of a method for the assessment of environmental influence of manufacturing systems.

ISO 20140 specifies a method for evaluating the energy efficiency of a manufacturing system and other factors, e.g. energy consumption, waste and release, etc., that influence the environment. The evaluation method provides guidelines to analyse the usage of energy by the manufacturing system and the effects of the manufacturing system on the environment. ISO 20140 systematically evaluates the environmental influence through analysing the manufacturing activities and the manufacturing system.

ISO 20140 is intended for discrete products/parts manufacturing systems, such as those used in forming, machining, painting, assembling, testing and other manufacturing processes in the production of aircraft, automobile, electric appliances, machine tools and their components, and other similar products.

The focused application domain of ISO 20140 is a manufacturing system that consists of the hierarchical structure built from individual manufacturing equipment, i.e. a work unit, a work centre, an area, and a factory. ISO 20140 provides evaluation methods for the influence on the environment, resulting from different manufacturing system configurations and from improvements of production management and individual manufacturing equipment operations.

The evaluation method and underlying concept of ISO 20140 can also be used as the foundation for the environmental influence evaluation for continuous processes and/or batch processes.

ISO 20140 can be used for:

— benchmarking of environmental influence with a generic manufacturing system or between different manufacturing systems for producing the same product,

— alternative studies of environmental influence for improving a current manufacturing process, reconfiguring a current manufacturing system/equipment, and designing a new manufacturing system,

— setting the top level target of environmental improvement and the breakdown to intermediate systems, work units and individual manufacturing equipment, and

— improving the shop floor operations by visualizing the actual status of environmental influence.

Expected users of ISO 20140 are:

a) managers for environmental conditions in a factory, site and enterprise;

b) engineers for process planning of products;

c) planners and designers for manufacturing systems; and

d) engineers and foremen that produce products by operating a manufacturing system.

The structure of ISO 20140 and the relationships between parts are outlined in Annex F.

Automation systems and integration — Evaluating energy efficiency and other factors of manufacturing systems that influence the environment —

Part 1: Overview and general principles

1 Scope

This part of ISO 20140 establishes an overview and general principles of a method for the assessment of environmental influence of manufacturing systems.

ISO 20140 specifies for the discrete products/parts manufacturing sectors a common foundation and methodology for energy efficiency and other factors of environmental influence evaluation, which enables sector specific methods to be applied in characteristic situations.

ISO 20140 enables an assessment to be made of the environmental influence of manufacturing processes, which can be used either to seek an overall reduction in negative influence or an increase in positive results.

The evaluation method of ISO 20140 is applicable to the environmental influence of a manufacturing system which consists of individual manufacturing equipment, and which is configured as a work unit, a work centre, an area or a factory.

ISO 20140 specifies the requirements for the environmental influence data to be captured from the individual manufacturing equipment, as the most granular data for aggregating along the manufacturing system hierarchy.

NOTE The evaluation method and underlying concept of ISO 20140 can be used as the foundation for the environmental influence evaluation for a continuous process and/or a batch process, in common with a discrete products/parts manufacturing process.

The following are outside the scope of ISO 20140:

— the environmental influence evaluation methodology of systems outside the manufacturing system boundaries (e.g. other systems of the same site or other systems of the entire enterprise);

— the environmental influence evaluation methodology to handle the complete product life cycle;

— the method and data for environmental evaluation which are specific to a particular industry sector, manufacturer, or machinery.

2 Normative references

The following referenced documents, in whole or in part, are normatively referenced in this document and are indispensable for its application. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 14040:2006, *Environmental management — Life cycle assessment — Principles and framework*

3 Terms, definitions and abbreviated terms

For the purposes of this document, the following terms and definitions apply.

3.1 Terms and definitions

3.1.1
actual production time
APT
time during a *work unit* (3.1.46) production, which includes only the value adding functions

Note 1 to entry: Actual production time is described in ISO 22400-2:—[1], 5.1.3.6.

3.1.2
area
physical, geographical or logical grouping of *resource* (3.1.39) determined by the *site* (3.1.41)

EXAMPLE It can contain process cells, production units, production lines, and storage zones.

[SOURCE: IEC 62264-1:—[2], 3.1.1]

3.1.3
construction, reconfiguration and retirement influence
CRR influence
environmental influence (3.1.14) of a manufacturing system at its life history steps of construction/reconfiguration and retirement

3.1.4
direct influence
environmental influence (3.1.14) resulting from actual product production by *direct operation* (3.1.5) of *manufacturing equipment* (3.1.29)

3.1.5
direct operation
mode of *manufacturing equipment* (3.1.29) which performs value adding functions in actual product production

3.1.6
energy
electricity, fuels, steam, heat, compressed air, and other like media

[SOURCE: ISO 50001:2011, 3.5, modified — Notes have been deleted.]

3.1.7
energy efficiency
ratio or other quantitative relationship between an output of performance, service, goods or *energy* (3.1.6), and an input of energy

EXAMPLE Conversion efficiency; energy required/energy used; output/input; theoretical energy used to operate/energy used to operate.

[SOURCE: ISO 50001:2011, 3.8, modified — Note has been deleted.]

3.1.8
enterprise
one or more organizations sharing a definite mission, goals, and objectives to offer an output such as a product or service

[SOURCE: ISO 15704:2000, 3.6]

1) To be published.

2) To be published. (Revision of IEC 62264-1:2003)

3.1.9
environment
surroundings in which an organization operates, including air, water, land, natural resources, flora, fauna, humans, and their interrelation

[SOURCE: ISO 14001:2004, 3.5, modified — Note has been deleted.]

3.1.10
environmental aspect
element of an organization's activities or products or services that can interrelate with the *environment* (3.1.9)

[SOURCE: ISO 14001:2004, 3.6, modified — Note has been deleted.]

3.1.11
environmental characteristics data
ECD
characteristics and/or performance specifications related to *environmental aspect* (3.1.10), both acquired by measurement and declared by the equipment suppliers

3.1.12
environmental impact
any change to the *environment* (3.1.9), whether adverse or beneficial, wholly or partially resulting from an organization's *environmental aspects* (3.1.10)

[SOURCE: ISO 14001:2004, 3.7]

3.1.13
environmental index
value that represents environmental efficiency and/or environmental influence related performance or characteristics

3.1.14
environmental influence
changes to the *environment* (3.1.9), whether adverse or beneficial, wholly or partially resulting from a manufacturing system's *environmental aspects* (3.1.10)

[SOURCE: ISO 14001:2004, 3.7, modified — "Environmental impact", "any change" and "organization" have been replaced by "environmental influence", "changes" and "manufacturing system".]

3.1.15
environmental influence footprint
sum of *environmental influence* (3.1.14) of a manufacturing system component as a *product* (3.1.35), used in the construction and reconfiguration step of a manufacturing system, based on a *life cycle assessment* (3.1.22)

3.1.16
factory
identified physical, geographical and/or logical component within a *site* (3.1.41), which is an organization with *resource* (3.1.39) for manufacturing products or providing services, and which is controlled by and reports to a business unit of a manufacturing *enterprise* (3.1.8)

Note 1 to entry: At least one factory is located within a site.

Note 2 to entry: A factory is the highest entity of a manufacturing system within a site.

3.1.17
indirect influence
environmental influence (3.1.14) resulting from activities that support actual product production by *direct operation* (3.1.5) of *manufacturing equipment* (3.1.29), in *indirect mode* (3.1.18) of manufacturing equipment and operation and maintenance of the *manufacturing support system* (3.1.30)

3.1.18
indirect mode
mode of *manufacturing equipment* (3.1.29) to support its *direct operation* (3.1.5)

EXAMPLE Idle/standby mode and maintenance.

3.1.19
input
material or energy flow that enters a *unit process* (3.1.42)

[SOURCE: ISO 14040:2006, 3.21, modified — "Product" has been removed from definition, and Note has been deleted.]

3.1.20
life cycle
<manufacturing system> finite set of generic phases and steps a system may go through over its entire *life history* (3.1.28)

[SOURCE: ISO 15704:2000, 3.11, modified — Concept domain has been added.]

3.1.21
life cycle
<product> consecutive and interlinked stages of a product system, from raw material acquisition or generation from natural resources to final disposal

[SOURCE: ISO 14040:2006, 3.1, modified — Concept domain has been added.]

3.1.22
life cycle assessment
LCA
<manufacturing system> compilation and evaluation of the inputs, outputs and the potential *environmental influence* (3.1.14) of a manufacturing system throughout its *life cycle* (3.1.20)

[SOURCE: ISO 14040:2006, 3.2, modified — "Environmental impact" and "product system" have been replaced by "environmental influence" and "manufacturing system", and concept domain has been added.]

3.1.23
life cycle assessment
LCA
<product> compilation and evaluation of the inputs, outputs and the potential *environmental impacts* (3.1.12) of a product system throughout its *life cycle* (3.1.21)

[SOURCE: ISO 14040:2006, 3.2, modified — Concept domain has been added.]

3.1.24
life cycle impact assessment
LCIA
phase of *life cycle assessment* (3.1.23) aimed at understanding and evaluating the magnitude and significance of the potential *environmental impacts* (3.1.12) for a product system throughout the *life cycle* (3.1.21) of the product

[SOURCE: ISO 14040:2006, 3.4]

3.1.25
life cycle influence assessment
phase of *life cycle assessment* (3.1.22) aimed at understanding and evaluating the magnitude and significance of the potential *environmental influence* (3.1.14) for a manufacturing system throughout the *life cycle* (3.1.20) of the manufacturing system

[SOURCE: ISO 14040:2006, 3.4, modified — "Impact" and "product system" and "product" have been replaced by "influence" and "manufacturing system".]

3.1.26
life cycle inventory analysis
<manufacturing system> phase of *life cycle assessment* (3.1.22) involving the compilation and quantification of inputs and outputs for a manufacturing system throughout its *life cycle* (3.1.20)

[SOURCE: ISO 14040:2006, 3.3, modified — "Product" has been replaced by "manufacturing system", and concept domain has been added.]

3.1.27
life cycle inventory analysis
<product> phase of *life cycle assessment* (3.1.23) involving the compilation and quantification of inputs and outputs for a product throughout its *life cycle* (3.1.21)

[SOURCE: ISO 14040:2006, 3.3, modified — Concept domain has been added.]

3.1.28
life history
actual sequence of steps a system has gone through during its lifetime

[SOURCE: ISO 15704:2000, 3.12]

3.1.29
manufacturing equipment
equipment which is operated for directly producing a product, in a manufacturing process

3.1.30
manufacturing support system
system which is used for providing the necessary *other resource* (3.1.32) to a manufacturing system

3.1.31
material
primary or secondary material, or intermediate product, that is used to produce a product

Note 1 to entry: Secondary material includes recycled material.

[SOURCE: ISO 14040:2006, definition 3.15, modified — "Raw material" has been replaced by "material" as the term, and "intermediate product" has been added to the definition.]

3.1.32
other resource
input (3.1.19) other than the *material* (3.1.31)

EXAMPLE *Energy* (3.1.6); coolant and lubricant; air conditioning and lighting.

Note 1 to entry: The term "other resource" is used in order to distinguish it from such *resources* (3.1.39) of a manufacturing system as *manufacturing equipment* (3.1.29) and *manufacturing support system* (3.1.30).

3.1.33
output
product (3.1.35), material or energy flow that leaves a *unit process* (3.1.42)

Note 1 to entry: Products and materials include raw materials, intermediate products, co-products and releases.

[SOURCE: ISO 14040:2006, 3.25]

3.1.34
process
set of interrelated or interacting activities that transforms *inputs* (3.1.19) to *outputs* (3.1.33)

[SOURCE: ISO 14040:2006, 3.11]

3.1.35
product
any goods or service

[SOURCE: ISO 14040:2006, 3.9, modified — Notes have been deleted.]

3.1.36
production line
collection of equipment dedicated to the manufacture of a specific number of products or product families

Note 1 to entry: A production line is a type of work centre.

[SOURCE: IEC 62264-1:—, 3.1.32]

3.1.37
release
emissions to air and discharges to water and soil

[SOURCE: ISO 14040:2006, 3.30]

3.1.38
residual CRR influence
CRR influence (3.1.3) of a manufacturing system and its components, which is still residual after offset through the specific term of CRR influence charge/offset process and/or at the time of retirement

3.1.39
resource
enterprise entity that provides some or all of the capabilities required by the execution of an *enterprise* (3.1.8) activity and/or business process

[SOURCE: ISO 15704:2000, 3.18]

3.1.40
reusable material
material (3.1.31) remaining after a manufacturing process which can be reused or recycled

EXAMPLE Chips as removed materials after machining; removed material after die casting.

3.1.41
site
identified physical, geographical and/or logical component grouping of a manufacturing *enterprise* (3.1.8)

[SOURCE: IEC 62264-1:—, 3.1.39]

3.1.42
unit process
most detailed activity element of a *process* (3.1.34) considered in the *environmental influence* (3.1.14) evaluation for which input and output data are quantified

[SOURCE: ISO 14040:2006, 3.34, modified — “Smallest element” and “life cycle inventory analysis” have been replaced by “most detailed activity element of a process” and “environmental influence evaluation”.]

3.1.43
waste
substances or objects which the holder intends or is required to dispose of

[SOURCE: ISO 14040:2006, 3.35, modified — Note has been deleted.]

3.1.44
work cell
equipment grouped together to produce a family of parts having similar manufacturing requirements within a production line

Note 1 to entry: A work cell is a type of work unit.

[SOURCE: IEC 62264-1:—, 3.1.43]

3.1.45
work centre
equipment element under an *area* (3.1.2) in a role-based equipment hierarchy that performs production, storage, material movement, or any other Level 3 or Level 4 scheduled activity

[SOURCE: IEC 62264-1:—, 3.1.44]

3.1.46
work unit
equipment element under a *work centre* (3.1.45) in a role-based equipment hierarchy that performs production, storage, material movement, or any other Level 3 or Level 4 scheduled activity

Note 1 to entry: A work unit is the most detailed collection of manufacturing equipment of a manufacturing system considered in the *environmental influence* (3.1.14) evaluation for which input and output data are quantified.

[SOURCE: IEC 62264-1:—, 3.1.45, modified — "Note 1 to entry" has been added.]

3.2 Abbreviated terms

APT Actual Production Time

CRR Construction, Reconfiguration and Retirement (of a manufacturing system)

ECD Environmental Characteristics Data

LCA Life Cycle Assessment

4 Manufacturing system and its environmental influence evaluation

4.1 Product life cycle and manufacturing system life history

4.1.1 Product life cycle and manufacturing system life cycle

The manufacturing process for producing a product is positioned at the intersection of the product life cycle, the manufacturing system life cycle and the business process, as illustrated in Figure 1. The product life cycle and the manufacturing system life cycle have common life cycle stages and phases, respectively, of design, production, operation and support, and retirement.

The product production at a factory may change depending on the change of product quantity and/or product mix corresponding to a customer order change, starting a new production of a newly designed or design changed product, and a manufacturing system configuration change.

The manufacturing system environmental influence at a factory may change depending on the product production changes, and changes in process plans for producing a product, and the manufacturing execution control, for improving the environmental influences.

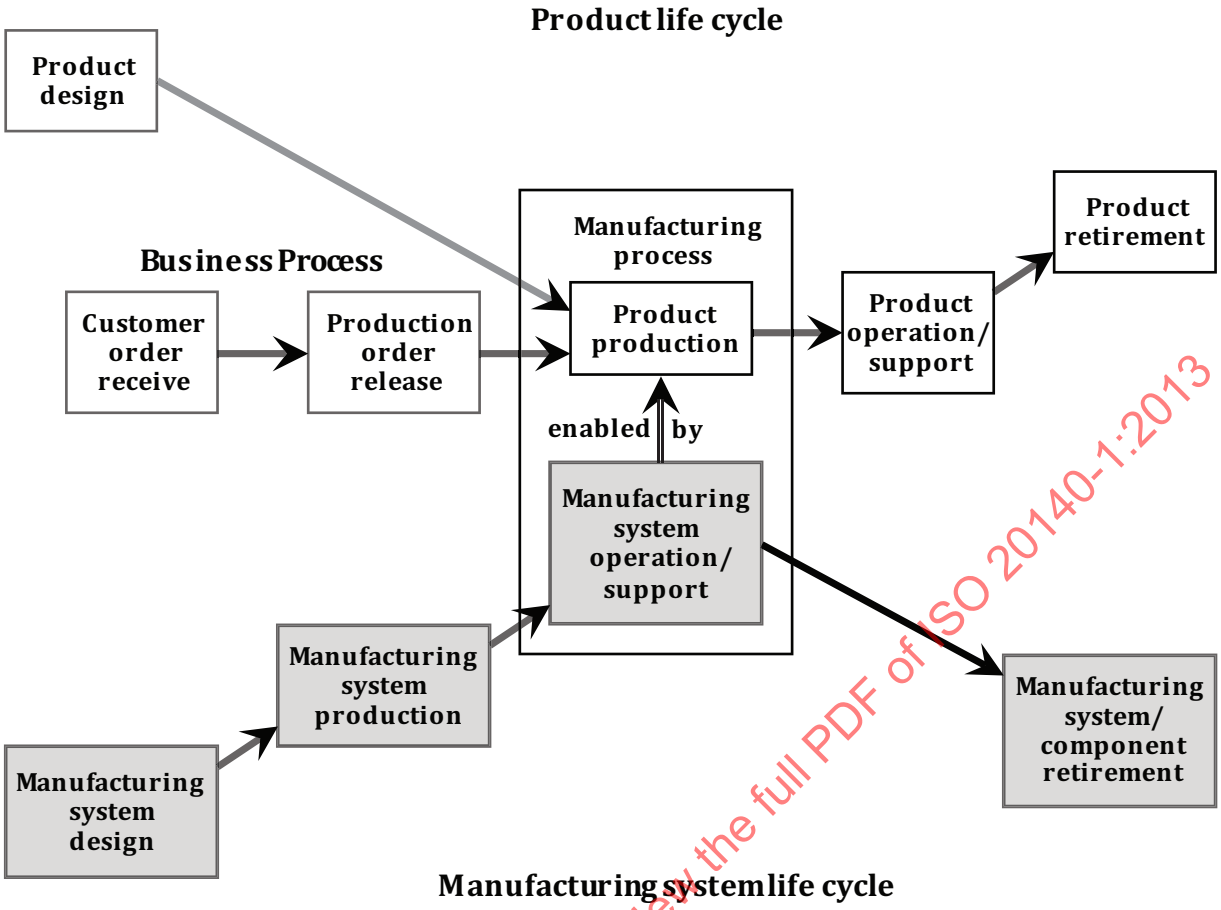

Figure 1 — Product life cycle and manufacturing system life cycle

4.1.2 Manufacturing system life history for its environmental influence evaluation

An environmental evaluation of a manufacturing system shall consider the whole life history steps of the system in addition to its operation step where actual production is executed, as illustrated in Figure 2.

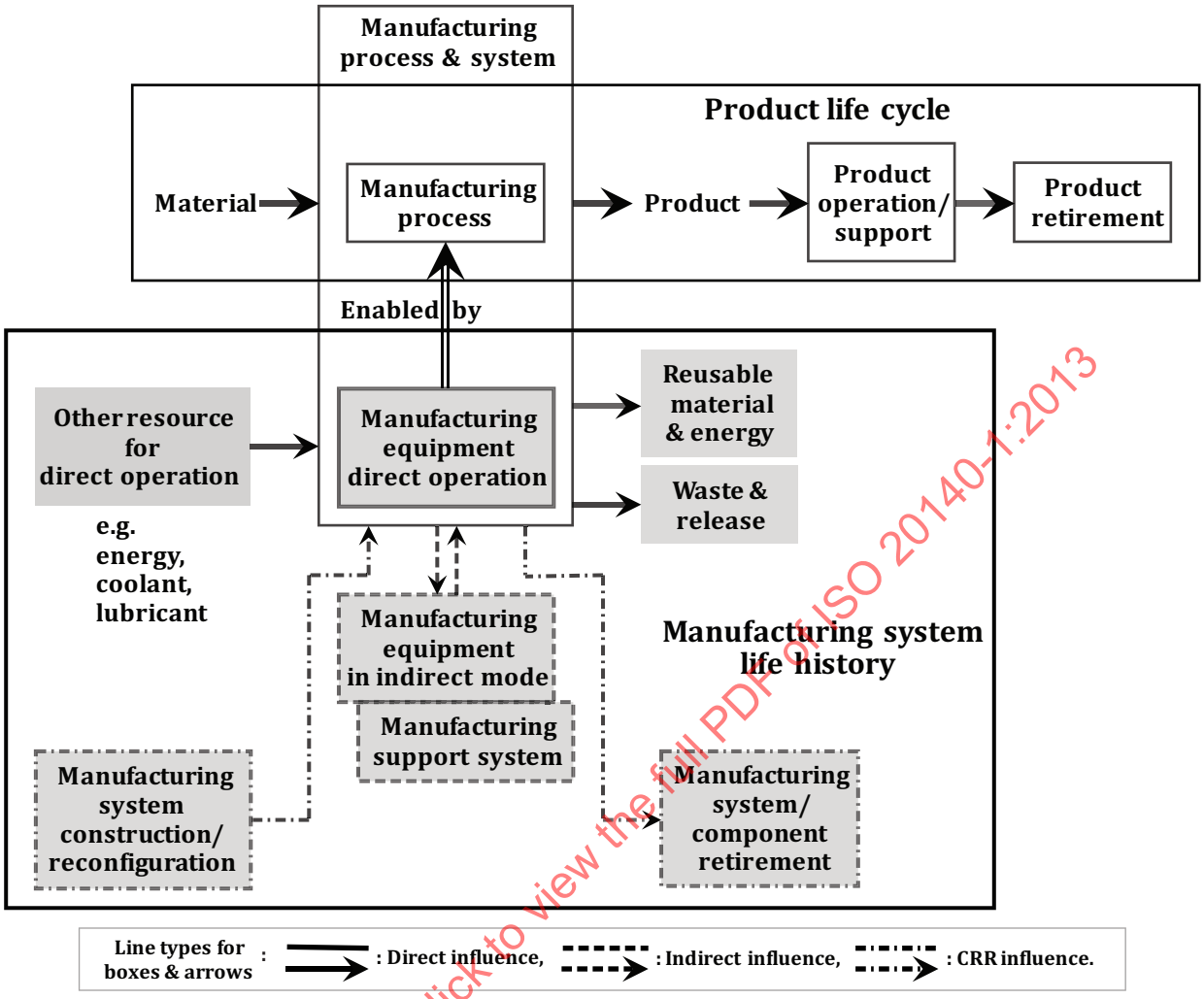

Figure 2 — Product life cycle and manufacturing system life history

Material and other resources, as the input to the manufacturing process that influences the environment, and product, reusable material and energy, and waste and release, as the output from the manufacturing process that influences the environment, are identified in Figure 2.

NOTE 1 Neither the product design stages nor the manufacturing system design phases (identified in Figure 1) are identified in Figure 2, because both product design and manufacturing system design are the given conditions for the environmental influence evaluation of a manufacturing system for actual product production for realizing the customer order under the business process.

NOTE 2 The life history concept is designed to identify the representation in time of activities, carried out through the life history with iterative nature, specified in ISO 15704:2000, 4.2.9 and explained in ISO 15704:2000, A.3.1.3.3, in relation to the life cycle specified in ISO 15704:2000, 4.2.8.

For environmental influence evaluation, every step of the life history of a manufacturing system shall be identified and its actual environmental influence data shall be acquired.

The life history steps of a manufacturing system for which significant environmental influences occur are:

— construction/reconfiguration,

— operation, and

— retirement.

The operation step of a manufacturing system is comprised of the direct operation mode and indirect mode of the manufacturing equipment, e.g. idle/standby mode and maintenance, and operation and maintenance of the manufacturing support system. The manufacturing system retirement step includes reuse, recycling and disposal of system components.

NOTE 3 The activities across the life history of a manufacturing system in relation to environmental influence are studied in Annex A.

4.2 Manufacturing system hierarchical structure

The manufacturing system is composed of a hierarchical structure of individual manufacturing equipment, placed into work units (work cells), aggregating through the work centre (production line) and areas to a factory as the largest extent of aggregation at the top node, as illustrated in Figure 3.

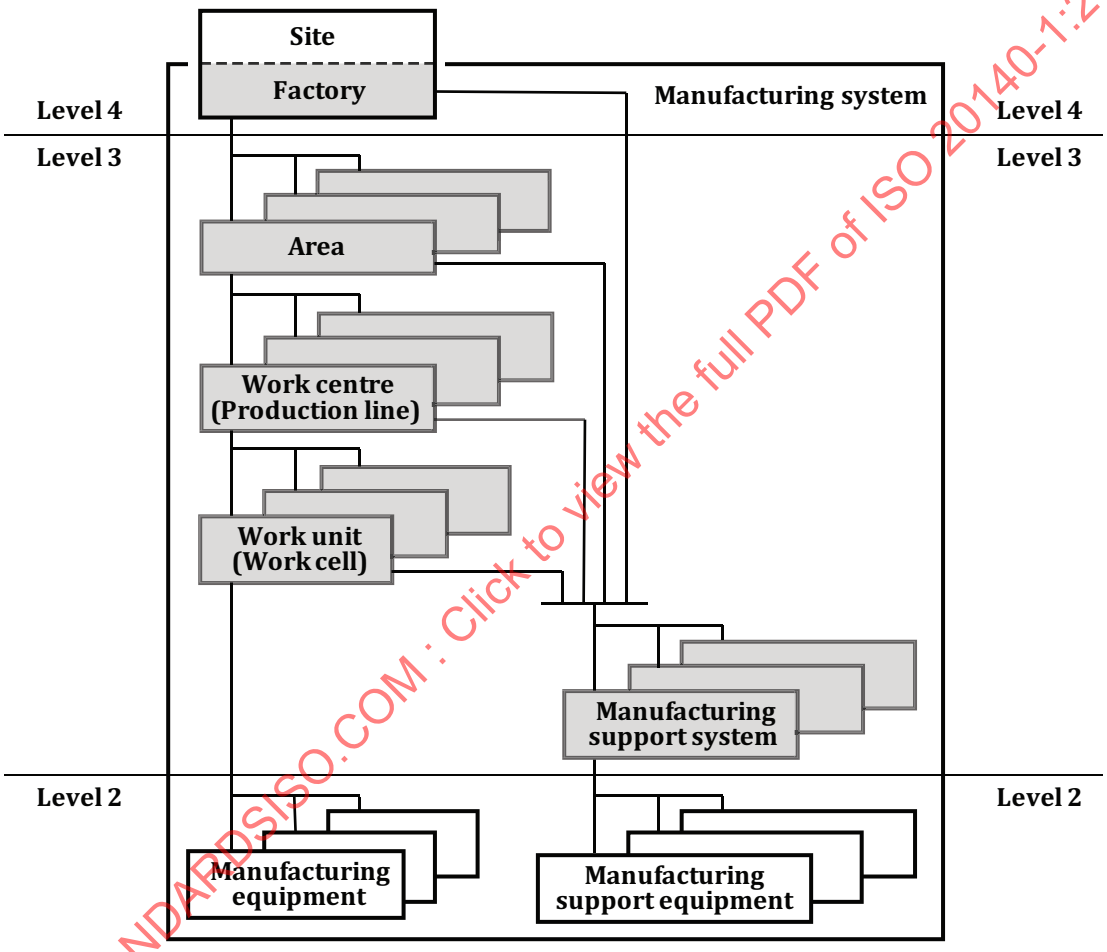

Figure 3 — Manufacturing system hierarchical structure

NOTE 1 The manufacturing system hierarchy, illustrated in Figure 3, is consistent with the role-based equipment hierarchy specified in IEC 62264-1:—, 5.3, except that factory is identified under the site. Level n in Figure 3 represents the corresponding Level n of the functional hierarchy level specified in IEC 62264-1:—, 5.2.1.

NOTE 2 The production line or work cell (shown in parentheses) represents a type of work centre or work unit, respectively, for discrete production.

NOTE 3 ISO 20140 focuses on Level 3, with the interface to Level 2 and Level 4. It acquires actual data from Level 2, receives production planning data from Level 4, and reports environmental index, as the result of environmental influence evaluation, to Level 4 (see Clauses F.4 to F.6).

4.3 Environmental influence evaluation

The environmental influence during the manufacturing system construction/reconfiguration, operation and retirement steps shall be evaluated by applying the standardized life cycle assessment (LCA) method, as specified in ISO 14040. For this evaluation, the manufacturing system is considered as the target product for the analysis by the LCA method.

An appropriate application of the LCA method shall carefully consider the characteristics of the manufacturing system and its life history. The following aspects are essential for a careful manufacturing system evaluation:

— the environmental influence shall consider evaluation for the whole manufacturing system life history, as shown in Figure 2;

— the environmental influence shall be evaluated corresponding to the different system operation modes, as explained in 5.2.1 and 5.2.2;

— the functional unit of the evaluation by the LCA method shall be determined with respect to output products of the manufacturing system, and shall be a basis for the system value evaluation discussed in 5.4.2.

A manufacturing system consists of relatively complicated system equipment, which is used for a long time and performs in various modalities: in mass production, variable products/variable volume production, and small volume/one-piece production. Depending on these characteristics of the manufacturing system, the environmental influence during system operation is very important. Therefore an influence evaluation at the operation step is mandatory, and influence evaluation at the construction/reconfiguration and retirement steps are optional. The importance of environmental influence during respective manufacturing system life history steps could vary according to the objectives of the evaluation and the characteristics of the manufacturing system concerned. In situations where manufacturing technology is mature and the manufacturing system is used for a long period, an operation step has greater importance. In situations where the manufacturing system is frequently constructed or re-configured due to rapid technology innovation and market changes, the retirement and construction/reconfiguration steps become more important.

5 Evaluation method of environmental influence

5.1 Methodology of environmental influence evaluation

The methodology of the environmental influence evaluation of ISO 20140 shall consist of methods for:

— collecting and organizing environmental influence data from the resource hierarchy for a manufacturing system;

— evaluating the contributions across various operation modes (direct operation, idle/standby mode and maintenance) of manufacturing equipment to the overall influence from the various steps in a life history of a manufacturing system, i.e. from construction/ reconfiguration, via operation, to retirement;

— ensuring the consistency between each view summary of the manufacturing system view and the output product view.

Individual manufacturing equipment data shall be able to:

a) represent every mode of individual manufacturing equipment activity, e.g. normal operation, idle/ standby mode and maintenance;

b) use interchangeably actual environmental performance acquired from the manufacturing system and environmental characteristics data (ECD) of manufacturing system component suppliers.

5.2 Unit process of manufacturing process

5.2.1 Process approach and system boundary of a process

For system environmental influence evaluation, a manufacturing system boundary shall be clearly determined. The basic object for evaluation is a process. A process can be determined at different scales or granularity, e.g. individual manufacturing equipment, a work unit (work cell), a work centre (production line), an area or a factory, depending on the evaluation objectives. Appropriate definitions of processes in respective expert domains shall be referenced. By combining the input and output of several processes, an aggregate process can be determined as a target for environmental influence evaluation.

For an environmental influence evaluation, the constituents of a process shall be the activities decomposed to a granularity which is sufficient for a requested accuracy of the evaluation. These constituents are unit processes in the standardized LCA method, as specified by ISO 14040, and can consist of activities that combine several work units (work cells) or a unit process can correspond to an activity of one work unit (work cell). The system boundary encapsulates these unit processes and externalizes their input and output, as illustrated in Figure 4.

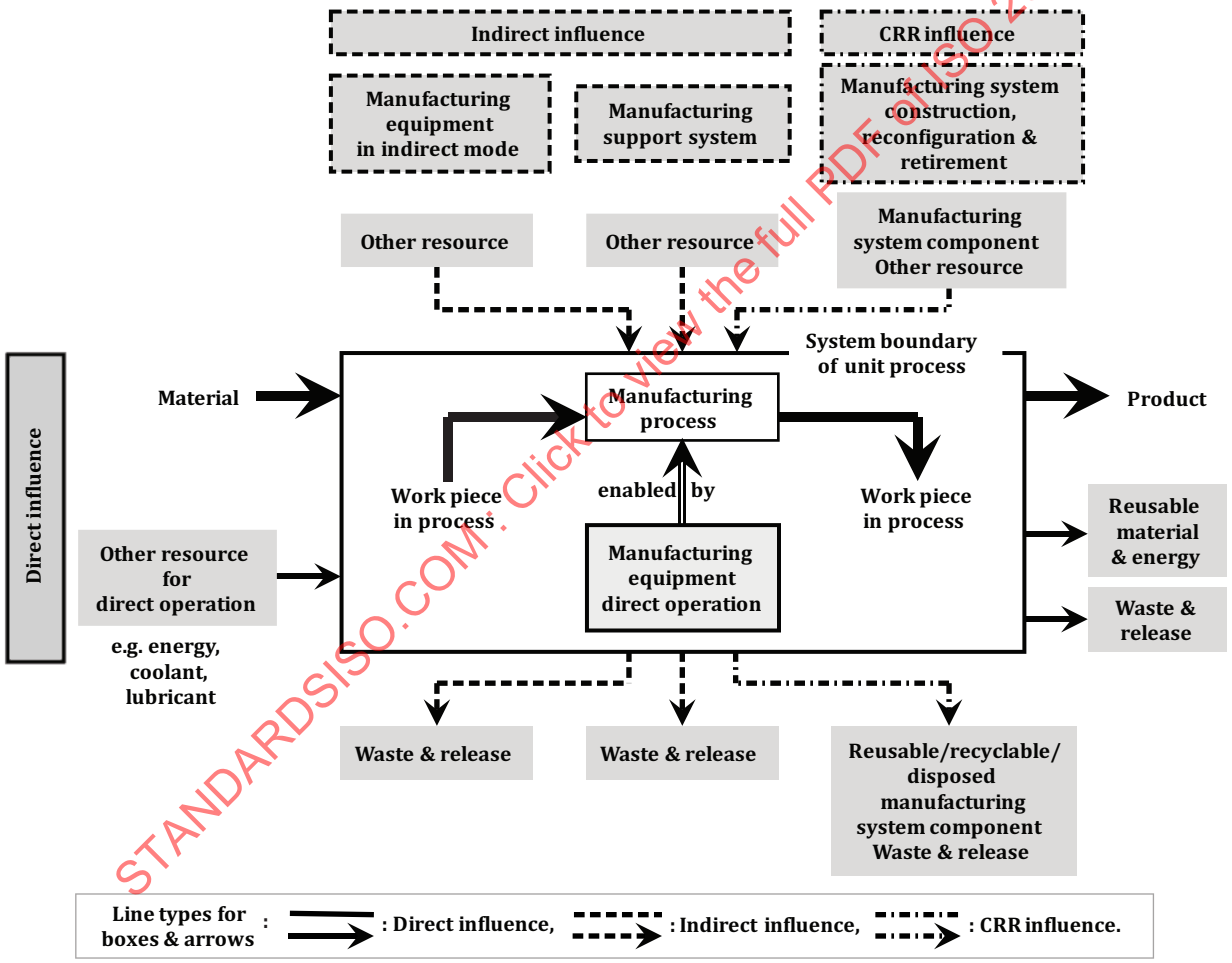

Figure 4 — Unit process model

NOTE 1 The responsibility of the organizational role with regard to environmental influence, in relation to the activities across the life history of a manufacturing system, is studied in Annex B.

NOTE 2 Examples of cases for environmental evaluation are shown in Annex C.

5.2.2 Unit process input and output

5.2.2.1 Input and output influence classification

Each input and output across the system boundary of the unit process concerned shall be enumerated and evaluated for environmental influence through the manufacturing system life history steps, as appropriate to the evaluation purpose, and shall be classified into one or more categories: direct influence, indirect influence and CRR influence.

Illustrated in Figure 4 are sources of influence resulting from input to and output from a unit process. These influences are divided into direct influence, indirect influence and CRR influence, with the former shown on the horizontal axis and the latter two on the vertical axis. The direct influence is associated with actual product production by direct operation mode of manufacturing equipment which perform value adding functions. The indirect influence is associated with supporting product production by the manufacturing equipment direct operation, e.g. indirect mode of manufacturing equipment and maintenance and operation of manufacturing support systems. The CRR influence is associated with the long term influences due to construction, reconfiguration and retirement of the manufacturing system.

NOTE 1 Input to/output from unit process, explained in 5.2.2.2 to 5.2.2.4, are summarized in Annex D.

NOTE 2 The time models specified in ISO 22400-2:—, Clause 5, provide one means for distinguishing direct operation from indirect mode of manufacturing equipment or indirect process activities within a work unit.

5.2.2.2 Direct influence

Input and output in the horizontal direction of Figure 4 are used/consumed by direct operation mode of manufacturing equipment, which performs value adding functions, and/or are contained in the output products. The input shall include material and other resource, and the output shall include product, reusable material and energy, waste and release. Material shall consist of raw material and parts for product production. Other resource for direct operation shall consist of energy and other consumed resources for product production, e.g. coolant, lubricant. Product represents the target products for the manufacturing system. Reusable material and energy, and waste shall consist of all input which is not contained in the target products and release represents all releases to the environment.

Work piece in process shall consist of all existing work pieces within the boundary of the target unit process, for a specified interval of time. Evaluation shall be performed for a specified time interval, such as a month or a year. Some input could be instantly processed and output is generated. Some input stays within a system boundary and could be used after some amount of time. In some cases, input material stays within a system boundary, without any direct output, during the evaluation interval. Similarly, output could be generated without any direct input.

5.2.2.3 Indirect influence

In the vertical direction of Figure 4, the left and centre input and output pairs represent indirect influence in support of manufacturing equipment direct operation. These pairs identify manufacturing equipment in indirect mode, which may include idle/standby mode and maintenance, and operation and maintenance of manufacturing support systems, e.g. power distribution systems, on-site power generation, oil/water/chemicals/gas/air supply/ treatment systems, lighting and air conditioning. The output includes waste and release.

5.2.2.4 CRR influence

The right side input/output pair in the vertical direction represents CRR influence that occurs in long time intervals. CRR influence is comprised of input to/output from manufacturing system construction/reconfiguration and retirement step. Input to the manufacturing system construction/reconfiguration step contains manufacturing system components, carrying the environmental influence footprint of the used system components and/or residual CRR influence of the reused system components, and used other resources. Output from the manufacturing system

retirement step contains residual CRR influence of the reusable, recyclable and/or disposed system components, and waste and release.

5.2.3 Consistent process approach throughout manufacturing system hierarchy

Those items specified for a unit process in 5.2.1 and 5.2.2, e.g. requirements for clear cut system boundary, identification of input to/output from a process, and the environmental influence classification of direct influence, indirect influence and CRR influence, shall be addressed consistently throughout every level of the environmental evaluation of the hierarchical structure from a work unit (work cell) to the entire manufacturing system being evaluated.

5.3 Environmental influence

By considering all of the other resource crossing the system boundary, system environmental influence, i_E, due to the manufacturing system is evaluated by summing the environmental influence from all unit process inputs and outputs, as follows:

$$i_E = \sum_{\text{unit process}} i_D + \sum_{\text{unit process}} i_I + \sum_{\text{unit process}} i_{CRR} \quad (1)$$

where

i_E is environmental influence;

i_D is direct influence;

i_I is indirect influence;

i_{CRR} is CRR influence.

5.4 Environmental index evaluation

5.4.1 Environmental efficiency

The concept of environmental efficiency, e_E, expressed as a function F of system value and system environmental influence shall be used as an index for environmental evaluation, as follows:

$$e_E = F(v_S, i_S) \quad (2)$$

where

e_E is environmental efficiency;

v_S is system value;

i_S is system environmental influence.

Based on this concept, appropriate functions F are elaborated by considering evaluation objectives, production conditions and associated environmental influences. System value and system environmental influence are measured by different units. For environmental efficiency evaluation, a reference system is set up. A relative value of index values of a target system and a reference system is a valid evaluation for environmental efficiency.

The explicit definition of a function *F* depends on respective use cases given in ISO 20140-2. For example, one of the definitions is given as follows:

$$e_E = \frac{v_S}{i_S} \tag{3}$$

where system value is determined as a useful physical output or added value from manufacturing system operations, and environmental influence is calculated based on system inventory data throughout the manufacturing system's life history by applying the method of LCA, specified in ISO 14040. Because system value and system environmental influence are calculated on different measures, the ratio of the target system environmental efficiency and the reference system environmental efficiency should be valid for evaluation.

5.4.2 System value

The system value and a method for its calculation shall be explicitly specified.

NOTE 1 ISO 20140-2 provides several means for determining system value.

EXAMPLE 1 System value could be product price, product quality and features, production volume, production lead time, and many other suitable definitions.

NOTE 2 Ideally, useful physical output or added value expresses system value. System parameters, e.g. system availability, material usage rate (yield), are related to system value, and are likely candidates for evaluation with respect to system environmental influence.

Useful system output directly related to system value shall be separated from other inventory data.

NOTE 3 This separation permits the itemization and differentiation of data, and facilitates quantifying the environmental improvement of a manufacturing system.

EXAMPLE 2 Reusable material and energy, waste and release from production processes are treated separately from the target products.

5.4.3 Basement data for life cycle inventory analysis/life cycle influence assessment

The environmental evaluation process, specified by ISO 20140-2, shall represent the basement data for life cycle inventory analysis and/or life cycle influence assessment of a manufacturing system and life cycle impact assessment of their output product, and/or all over their site and/or entire enterprise.

EXAMPLE Requirements and/or guidelines for that analysis and assessment are specified and/or given by the standards for:

— life cycle assessment, greenhouse gases, carbon footprint and material flow cost accounting, developed by ISO/TC 207 (see References [3], [5], [8], [9], [10] and [6]);

— energy management systems, developed by ISO/TC 242 (see Reference [11]);

— product and/or product system design, developed by ISO/TC 207 and IEC/TC 111 (see References [2], [4], [7] and [12]).

6 Evaluation process of environmental influence

6.1 Evaluation process of environmental index

The method for evaluating an environmental index for a manufacturing process shall be applicable at every process level and provide a consistent summary mechanism for the manufacturing system and/or product (group) concerned.

The process for evaluating the environmental index of a manufacturing process shall be capable of evaluating at any level of the manufacturing system concerned and/or product (group) concerned, the

summary of them shall be consistent, and the evaluations and the results of the evaluations should be associative and commutative.

NOTE A process model for specifying the method for the evaluation of environmental index, specifying environmental efficiency and system value, is specified by ISO 20140-2 (see Clause F.4).

6.2 Aggregation process of environmental influence

The environmental influence evaluation shall acquire data from individual manufacturing equipment within work units (work cell) and aggregate those data at the level of a unit process. Aggregation along the hierarchical structure of the manufacturing system up to a factory level shall follow.

NOTE A process model for environmental influence aggregation is given in ISO 20140-3 (see Clause F.5).

6.3 Allocation/charge process of indirect/CRR influence

6.3.1 Allocation/charge method of indirect/CRR influence

The environmental influence evaluation method shall be capable of ensuring the consistency of each view summary of the manufacturing system view and the product view, by allocating the indirect influence and charging CRR influence onto the proper direct influence element.

NOTE 1 The process model, for specifying the method for the evaluation of indirect influence and/or CRR influence, and for the allocation of indirect influence and/or for the charge of CRR influence onto the proper direct influence element, is given in ISO 20140-4 (see Clause F.6).

NOTE 2 The knowledge and best practice of cost accounting can be applied to ISO 20140-4, with respect to measuring and evaluation of indirect influence and CRR influence, and to planning, calculating and offsetting of allocation of indirect influence and/or charge of CRR influence onto the proper direct influence element.

Residual CRR influence shall be re-evaluated by following the offset result at the end of specific term of CRR influence charge/offset process.

6.3.2 LCA method for CRR influence

The manufacturing system construction/reconfiguration influence, out of CRR influence, shall be evaluated by LCA method, e.g. specified in ISO 14040, considering that the constructed/reconfigured manufacturing system and its components are treated as a target product for the analysis by the LCA method. Examples of CRR influence in construction/reconfiguration step, on which the LCA method shall be applied, are the environmental influence footprint of the used system components and the residual CRR influence of the reused system components.

The same consideration shall be applied for the manufacturing system retirement environmental influence, out of the CRR influence, to derive the environmental influence by that process. An example of CRR influence in the retirement step, on which LCA method shall be applied, is the residual CRR influence of the reusable, recyclable and disposed system components.

6.3.3 End of life consideration

At the time of the retirement of obsolete system components of a manufacturing system, if the system components are still active, or have some production capacity, and could be reused for other manufacturing systems, residual CRR influence corresponding to this remaining capacity can be removed from the manufacturing system evaluation if it was previously included. If the retired system component is effectively reused for another purpose, then the corresponding part of the residual CRR influence of the retired system component shall be subtracted from the residual CRR influence of the original manufacturing system, and shall be carried by each system component and succeeded to the next manufacturing system. In the case of system component retirement without reuse, the residual CRR influence/system value of the retirement system component from its current status until the complete expenditure of its capacity shall be subtracted from the residual CRR influence/system value

of the manufacturing system. No generally accepted procedure for active system or system component retirement exists, therefore it shall be explicitly specified.

7 Data for environmental influence evaluation

7.1 General

To perform an environmental influence evaluation of a manufacturing system, information concerning manufacturing activities is necessary. By clearly defining these information data items, it is possible to perform unambiguous environmental influence evaluation.

NOTE 1 The details of such data items, their data format and the requirements for data acquisition are specified in ISO 20140-5.

NOTE 2 ISO 20140 can be applied in many versatile use cases, for various purposes and various concerns or views, for environmental influence evaluation. This part of ISO 20140 specifies conformance classes, for providing common guidelines for data classification (see Annex E).

7.2 Data categories for environmental influence evaluation

7.2.1 General

Data categories required for environmental evaluation by capturing actual data, aggregating environmental influence along with hierarchical structure of a manufacturing system and allocating/charging indirect/CRR influence onto proper direct influence elements, shall include actual environmental data elements and reference data elements.

7.2.2 Actual data

To perform the environmental influence evaluation, the following actual data shall be collected:

— material tracking data;

— direct influence data of individual manufacturing equipment in direct operation mode;

— indirect influence data of indirect mode of individual manufacturing equipment, and operation and maintenance of a manufacturing support system;

— CRR influence data.

7.2.3 Reference data

To perform the environmental influence evaluation, many aspects of the manufacturing system shall be included. To identify these aspects, a set of reference data shall be collected so that the range of participating unit processes and their respective inputs and outputs can be determined. These reference data shall be collected with at least the following three categories of information:

— Group 1: process plan data;

— Group 2: manufacturing process data;

— Group 3: manufacturing system data.

7.3 Actual data in operation step

7.3.1 General

Actual data from individual manufacturing equipment and from manufacturing support systems shall be collected to perform the identification of and calculation of environmental influences, as specified in 5.2.2 (see also Annex D).

7.3.2 Actual data of manufacturing equipment in operation step

a) Manufacturing equipment operation data

Environmental influence data, under the operation step, shall be acquired from individual manufacturing equipment, which shall be capable of distinguishing direct operation mode and indirect mode.

b) Data of input to/output from manufacturing process

Data of input to/output from the manufacturing process, including material tracking data, shall be acquired.

7.3.3 Actual data of manufacturing support system in operation step

a) Manufacturing support system operation data

Environmental influence data, under the operation step, shall be acquired from manufacturing support systems, which shall be capable of distinguishing operation mode and maintenance.

b) Data of input to/output from manufacturing support system

Data of input to/output from the manufacturing support system shall be acquired.

7.4 Actual data in construction/reconfiguration and retirement step

7.4.1 General

Actual data from the manufacturing system construction/reconfiguration and retirement step shall be collected to carry out identification and calculation of environmental influences, as specified in 6.3 (see also Annex D).

7.4.2 Actual data in construction/reconfiguration step

Actual data of input to/output from the manufacturing system construction/reconfiguration step shall be acquired.

7.4.3 Actual data in retirement step

Actual data of input to/output from the manufacturing system/component retirement step shall be acquired.

7.5 Reference data

7.5.1 General

To perform the environmental influence evaluation, a set of reference data shall be collected so that the range of participating unit processes and their respective inputs and outputs can be determined, correctly aggregating environmental influence along with the hierarchical structure of a manufacturing system, and correctly allocating/charging indirect/CRR influence onto proper direct influence elements (see Clauses F.4, F.5 and F.6).

7.5.2 Group 1: Process plan data

The following data shall be referenced to identify each process within the manufacturing process for tracking the product view:

— the process plan data of each product at the level of parts routing.

7.5.3 Group 2: Manufacturing process data

The following data shall be referenced to identify each process within the manufacturing process for tracking the production control view:

— the operation plan/status report of a manufacturing system;

— the production plan/status report of production control, and the execution plan/status report of manufacturing execution.

7.5.4 Group 3: Manufacturing system data

The following data shall be referenced to identify each process within the manufacturing system hierarchy:

— the hierarchical structure of a manufacturing system;

— the specification of manufacturing equipment;

— the specification of manufacturing support systems;

— the service zone of each manufacturing support system.

7.6 Environmental characteristics data (ECD)

Fundamental requirements and guidelines for ECD are specified in ISO 20140-5.

7.7 Existing data standards

Many of the data related to the definition and operation of manufacturing systems have been standardized already in related International Standards. In such cases, existing International Standards should be referred to and extended, as necessary.

EXAMPLE Data related to product production, manufacturing system operation, and product life cycle are specified by the International Standards for process planning, resource usage management, and product life cycle support, developed by ISO/TC 184/SC 4 (see References [13], [14] and [15]).

Annex A
(informative)

Activity model of manufacturing system life history and its environmental influence

A.1 IDEF-Env Notation (IDEF0-Env: IDEF0 for environmental influence of manufacturing process)

IDEF0 is designed and has been used as an illustrating tool for understanding the manufacturing processes and the effect/influence analysis of process improvements.

NOTE IDEF0 is established in Reference [23].

The original IDEF0 notation is illustrated in Figure A.1 a) (corresponding to Figure 3 in the original IDEF0 document[23]).

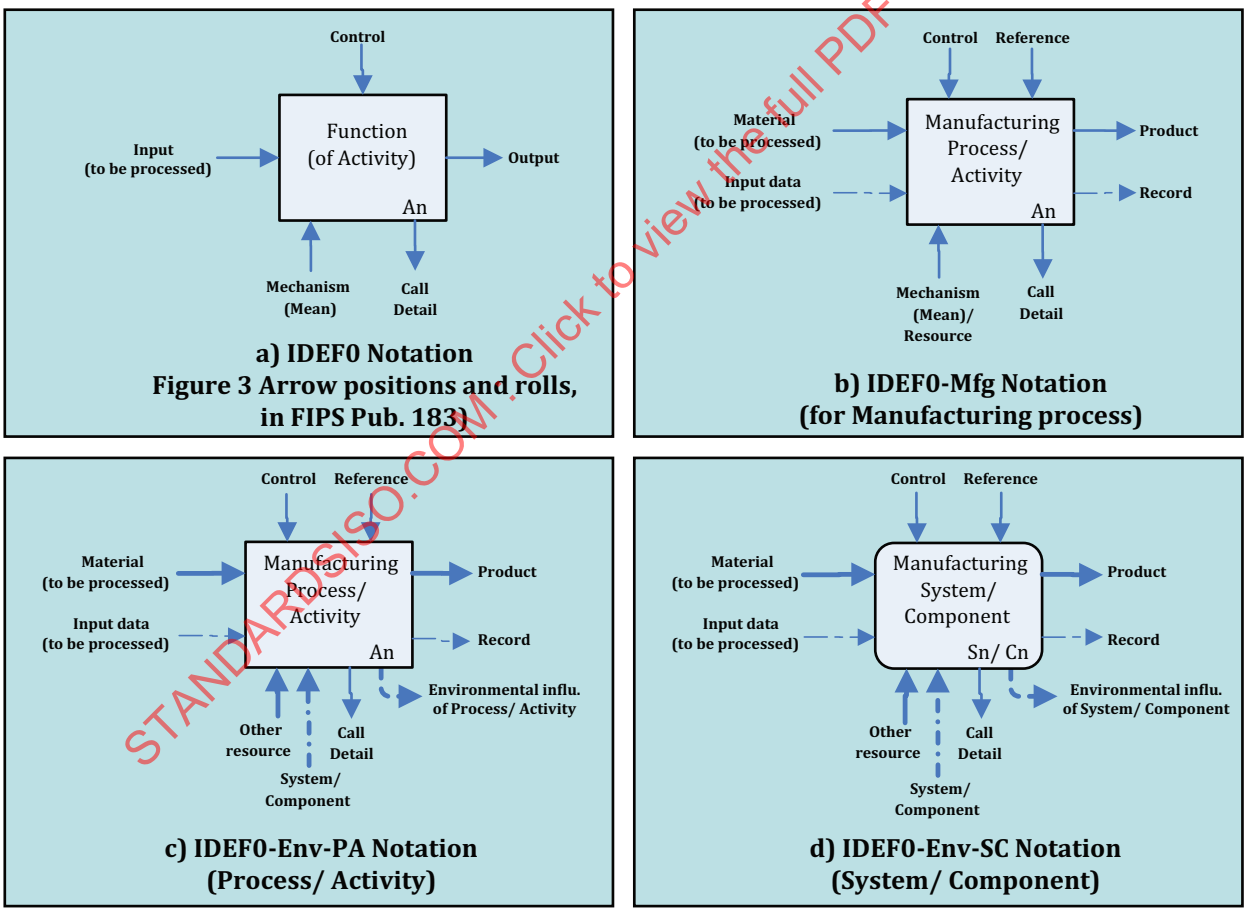

Figure A.1 — IDEF0-Env Notation

IDEF0-Mfg notation, used for representing the manufacturing process/activity, is illustrated in Figure A.1 b), with following modifications of original IDEF0 notation:

— Manufacturing Process/Activity (An) is positioned at Function (of Activity);

— Material and Input data are positioned at Input;

— Product and Record are positioned at Output;

— Reference is added at the next to Control;

— Resource is added at Mechanism (Mean).

IDEF0-Env is designed for illustrating the environmental influence of the manufacturing process, to be able to succeed the accumulated studies on manufacturing process/activity, by applying IDEF0/IDEF0-Mfg.

The notations of IDEF0-Env are illustrated in Figure A.1 c) to represent the manufacturing process/activity, and in Figure A.1 d) to represent the manufacturing system/system component, and are succeeding the notation of IDEF0-Mfg, with following modifications:

a) System/Component and Other resource are placed at Mechanism (Mean)/Resource;

b) Environmental influence is to be placed at the right end of bottom line, next to Call Detail in IDEF0.

A.2 Manufacturing process and its influence to the environment

A.2.1 General

Activity models of manufacturing system life history and its environmental influence are illustrated in Figure A.2 to Figure A.6.

Figure A.2 to Figure A.4 illustrate from the top level, 1st level and 2nd level decomposition of a manufacturing process and its influence to the environment.

A.2.2 Top level manufacturing process and its influence to the environment (A.0)

Figure A.2 illustrates the top level over all view of manufacturing process and its influence to the environment.

A.2.3 1st level manufacturing process and its influence to the environment (A.0-1)

Figure A.3 illustrates manufacturing process and its influence to the environment, as the 1st level analysis, i.e. as the next to top level of Figure A.2, with three paths of:

— design product/engineer production path of A1;

— manufacturing system CRR path of A2 and A5, respectively;

— plan production/procure material and produce product (Level 1) path of A3 and A4, respectively.

A.2.4 2nd level manufacturing process and its influence to the environment (A.0-2)

The 2nd level decomposition of manufacturing process and its influence to the environment, is illustrated in Figure A.4:

— A1 is decomposed into design product (A11) and engineer production (A12);

— A2 is decomposed into design manufacturing system (A21), construct new manufacturing system or reconfigure current manufacturing system (A22) and resultant manufacturing system (S23);

— A3 is decomposed into plan production (A31) and procure material (A32);

— A4 is decomposed into control manufacturing execution (A41) and produce product (Level 2) (A42);

— A5 retire manufacturing system is not further decomposed.

NOTE The activity Produce Product (by operate a manufacturing system or equipment) is identified in three levels of:

— A4: Produce Product (Level 1) (by operate a manufacturing system), in Figure A.3;

— A42: Produce Product (Level 2) (by operate a manufacturing system), under A41: Control manufacturing execution, in Figure A.4;

— A421: Produce Product (Level 3) (by operate manufacturing equipment), in Figure A.6.

A.3 Positioning of the actual manufacturing activity

Actual manufacturing activity, as illustrated in Figure A.4, is produce product (Level 2) by operate manufacturing system (A42), under the control manufacturing execution (A41), at the cross point of three paths of:

— design product/engineer production path of:
  — design product (A11), and
  — engineer production (A12);
— manufacturing system CRR path of:
  — design manufacturing system (A21),
  — construct new manufacturing system or reconfigure current manufacturing system (A22), and
  — retire manufacturing system (A5);
— plan production and produce product (Level 1) path of:
  — plan production (A31), and
  — procure material (A32).

A.4 Change causes of product production

Environmental influence of manufacturing system/process is affected by the external disturbances of:

— (1) Design and engineering based control (ΔA):
  — (1-1) Design and develop new product;
  — (1-2) Change product design;
  — (1-3) Change production process;
— (2) Manufacturing system based control (ΔB):
  — (2-1) Plan new manufacturing system;
  — (2-2) Plan to reconfigure current manufacturing system;
— (3) Production based control (Deviation of mass of product/product mix, ΔC):
  — (3-1) Plan production order;
  — (3-2) Receive customer order and release production order.

A.5 Environmental engineering on manufacturing system and/or process

Figure A.5 illustrates the decomposition of production engineering process (A12x).

The engineer production (A12), as illustrated in Figure A.5, is decomposed into four stages of design material (A121), plan part routing (macro process planning) (A122), design fixture and tool (A123), define manufacturing condition (micro process planning) (A124), and prepare numerical control program (A125).

The activities of design material (A121), plan part routing (macro process planning) (A122) and define manufacturing condition (micro process planning) (A124) are the key components of the engineer production (A12), by defining manufacturing process, for governing the environmental influence for producing given designed product using current manufacturing system.

The design product (A11), as illustrated in Figure A.4, initially determines the environmental influence required to produce that specific designed product, and that design product (A11) is requested to change the product design for realizing the feedback from design material (A121) and plan part routing (macro process planning) (A122) under engineer production (A12), as illustrated in Figure A.5.

The design manufacturing system (A21), as illustrated in Figure A.4, is another key player of environmental engineering, for planning a new manufacturing system or reconfiguring current manufacturing system/system component, which governs the environmental influence required to produce that specific product, and that design manufacturing system (A21) is requested to change current manufacturing system for realizing the feedback from plan part routing (macro process planning) (A122) under engineer production (A12), as illustrated in Figure A.5.

A.6 Production and monitoring of environmental influence

Figure A.6 illustrates produce products (Level 3) (A421) and supporting indirect activities of A422 and A423, as the decomposition of A.42 and the decomposition of manufacturing system (S23).

The manufacturing system (S23) is decomposed into manufacturing equipment (C231) and manufacturing support system (S232).

The produce product (Level 3) by operate manufacturing equipment (A421) as the direct influence, is supported by two activity groups of be in indirect mode of manufacturing equipment (A422) and maintain and operate manufacturing support system (A423), as the indirect influence.

The activities under be in indirect mode of manufacturing equipment (A422) are further decomposed into two, respectively into a mode of maintain manufacturing equipment (A4221) and be in idle/standby mode of manufacturing equipment (A4222).

The activities under maintain and operate manufacturing support system (A423) are further decomposed into maintain manufacturing support system (A4231), and operate manufacturing support system (A4232).

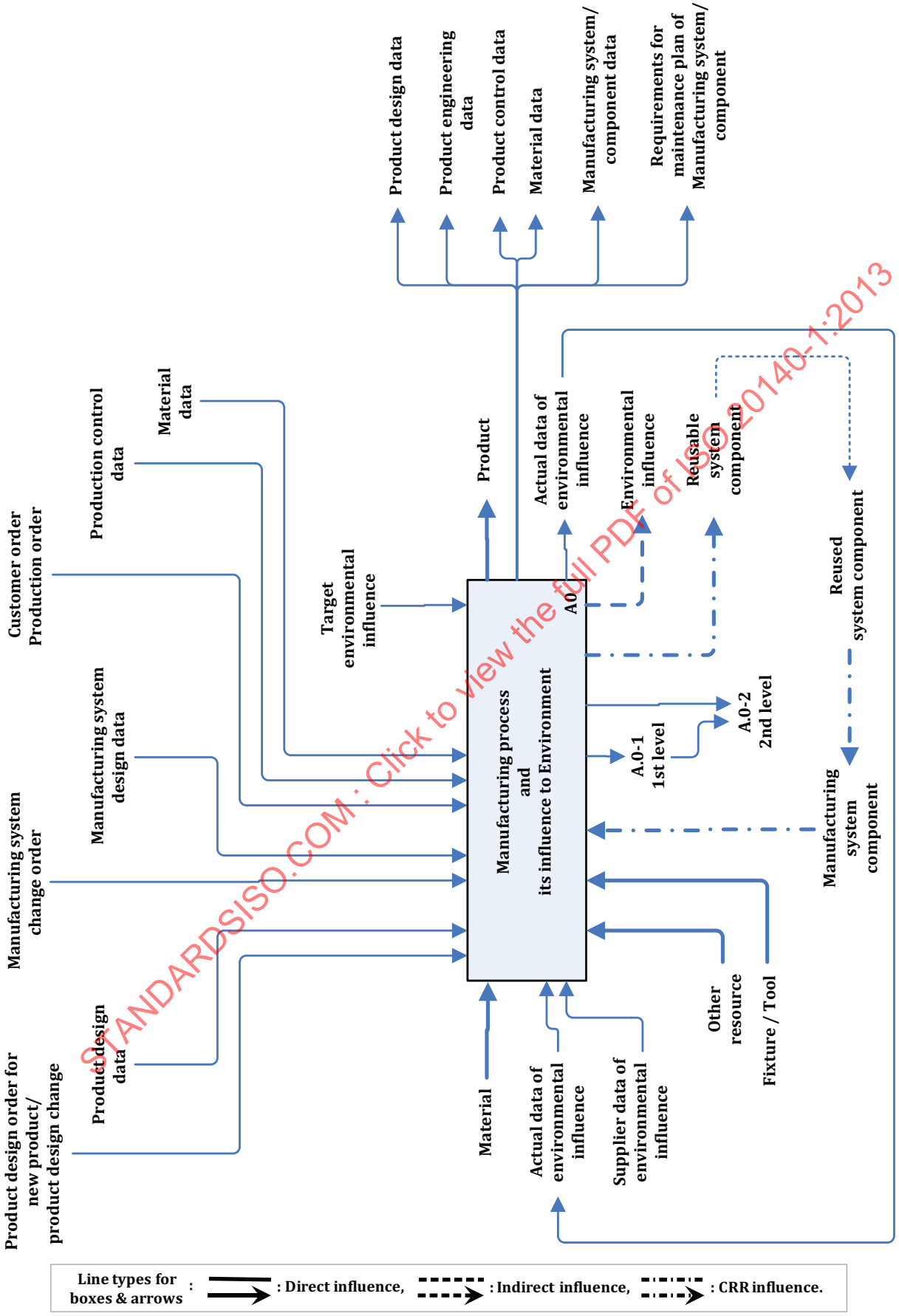

Figure A.2 — Manufacturing process and its influence to the environment: Top level (A.0)

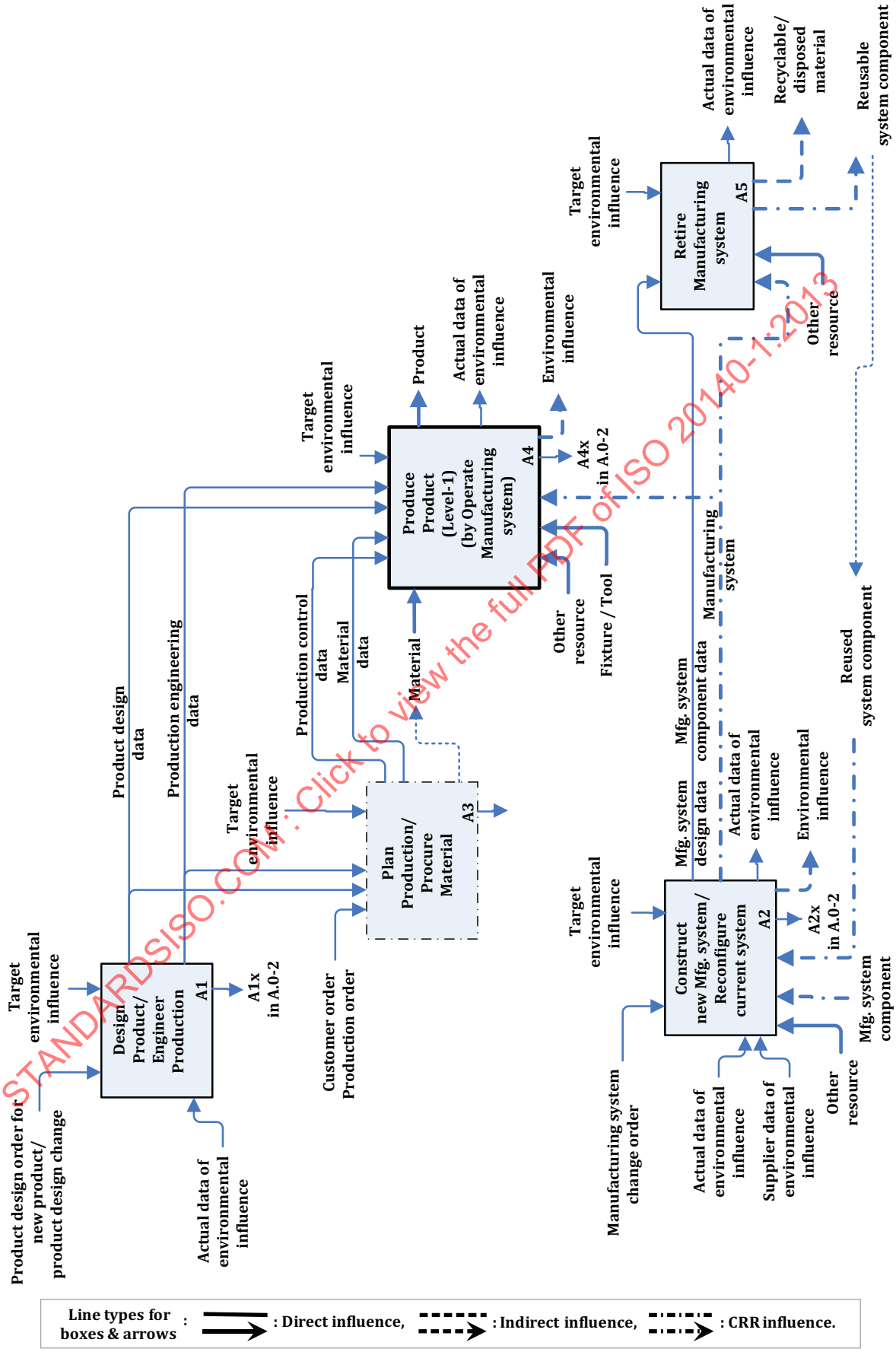

Figure A.3 — Manufacturing process and its influence to the environment: 1st level (A.0-1)

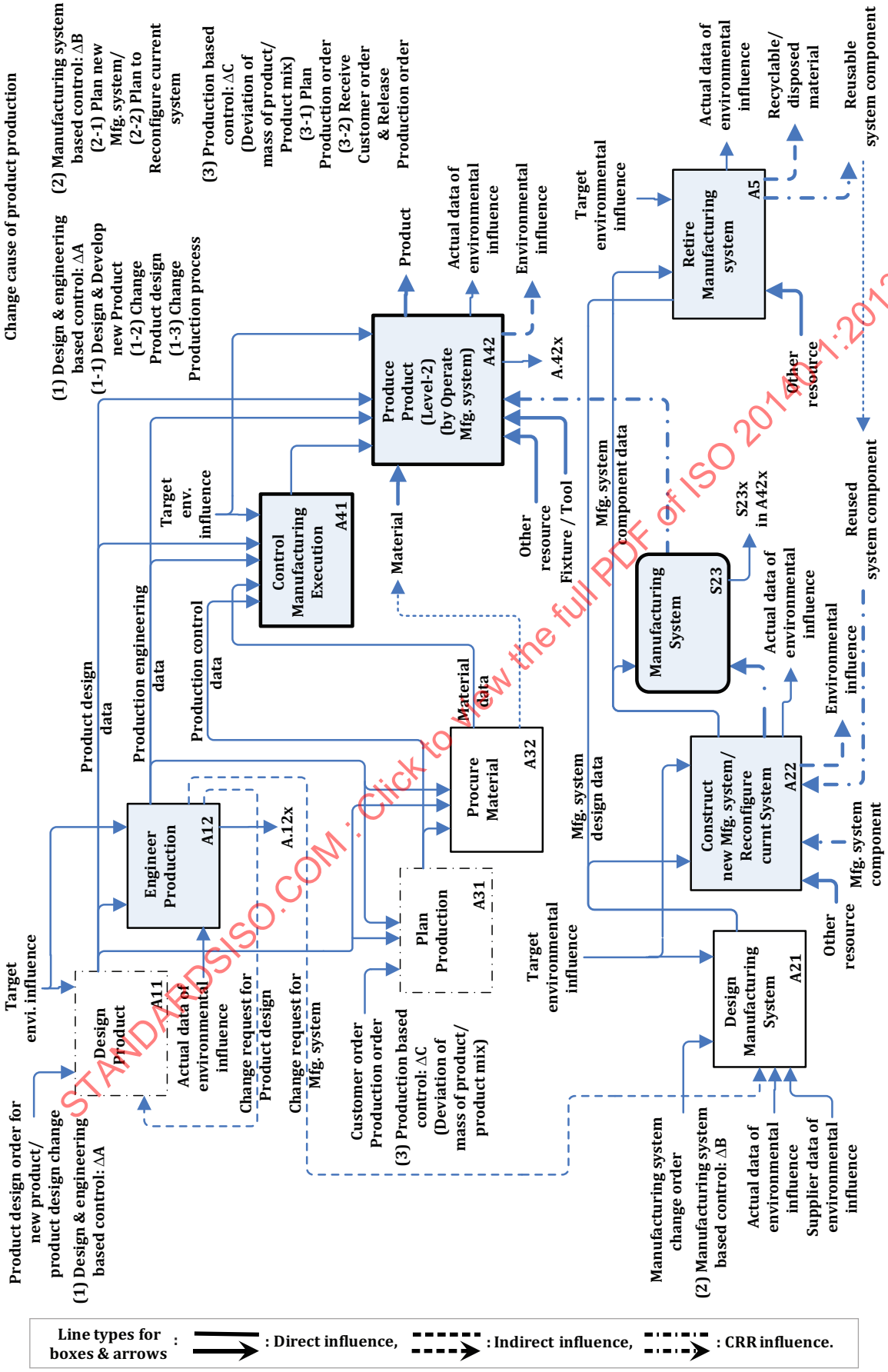

Figure A.4 — Manufacturing process and its influence to the environment: 2nd level (A.0-2)

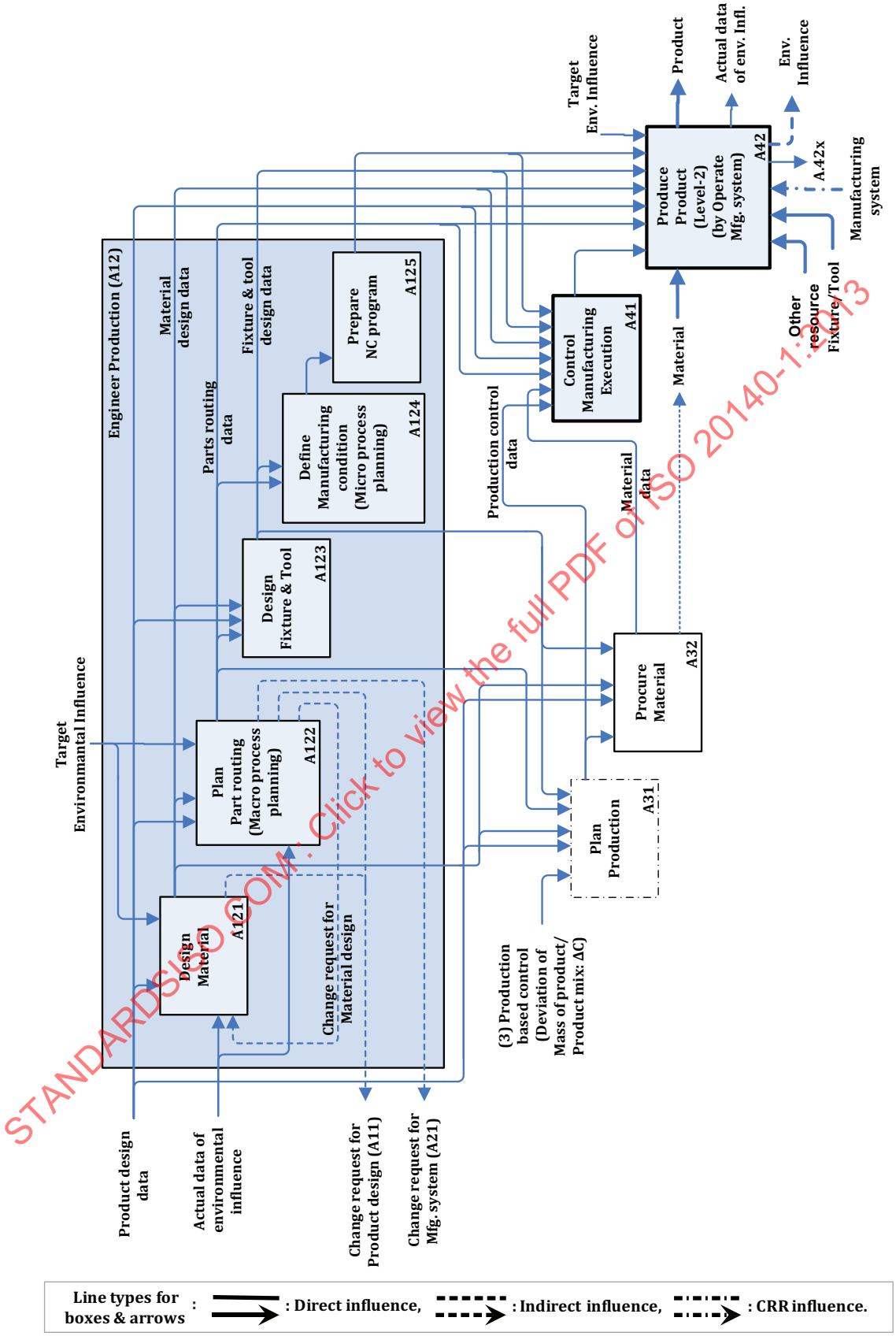

Figure A.5 — Production engineering (A12x)

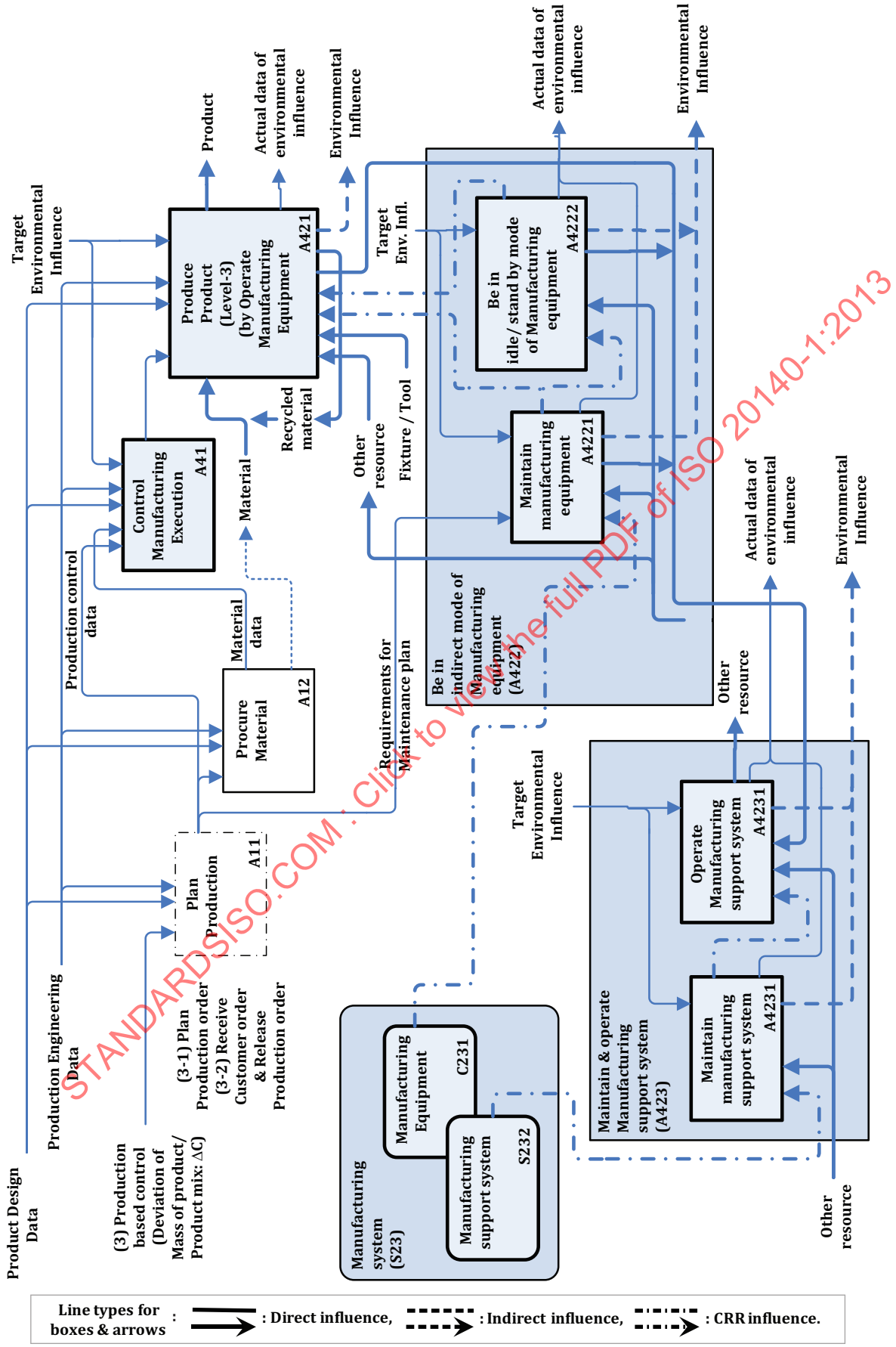

Figure A.6 — Produce products (Level 3) (A421) and its support (A422 and A423)

Annex B
(informative)

Responsibility of organization with regard to environmental influence

B.1 Responsibility for improving environmental influence

Each functional organization contributes to improving the environmental influence corresponding to its area of responsibility in manufacturing process and/or activity.

B.2 Influence responsibilities

Table B.1 identifies relationships between functional organizations and their responsibilities relating to environmental influence at an idealized factory. Table B.1 indicates the diversity of responsibilities for improving environmental efficiency.

Table B.1 — Functional organizations and their responsibilities for environmental influence

Functional organization	Activity	Environmental influence		
		Direct influence	Indirect influence	CRR influence
Product design	Design product (A11)	Define requirements for product	n.a.	Define requirements for planned products
Production engineering	Design material (A121)	Define requirements for manufacturing process	n.a.	Define planned materials for planned products
	Plan parts routing (Macro process plan) (A122)	Define manufacturing process	n.a.	Define manufacturing process for planned products
	Define manufacturing condition (Micro process plan) (A124)	Define manufacturing condition	n.a.	n.a.
Manufacturing system design	Design manufacturing system (A21)	Define manufacturing system capability & performance	Define manufacturing system capability & performance	Define manufacturing system & control CRR activities
Product production	Control manufacturing execution (A41)	Control manufacturing execution	Control manufacturing execution	n.a.
	Produce product (Level-3) (A421)	Operate manufacturing equipment	Control indirect mode of manufacturing equipment	n.a.
Manufacturing system maintenance	Maintain manufacturing equipment (A4221)	Maintain manufacturing equipment	Maintain manufacturing equipment	n.a.
Manufacturing support system	Maintain & operate manufacturing support system (A423)	n.a.	Maintain & operate manufacturing support system	n.a.

Table B.1 identifies the relationships between functional organizations and their responsibilities relating to the environmental influence, as follows:

— functional organization and its responsible activity, identified in Annex A, are listed by rows;

— classes of environmental influence, such as direct influence, indirect influence and CRR influence, are listed by columns;

— at the cross point cell of specific row and specific column, the responsibility of the functional organization for the specific activity related to the specific class of environmental influence is identified.

The entity identified by each cell in Table B.1 as being responsible for the specific class of environmental influence of the specific functional organization activity should contribute to the respective influence.

Annex C
(informative)

Use cases of ISO 20140

C.1 General

The use cases of ISO 20140 in this annex are identified with following two views:

— View 1: Purpose of and situations for environmental evaluation;

— View 2: Activities through manufacturing system life history.

C.2 Purpose of and situations for environmental evaluation (View-1)

C.2.1 Environmental evaluation of manufacturing system

C.2.1.1 Evaluation is based on general environmental data

General evaluation of a manufacturing system is done without assuming usage of particular machines or equipment, e.g. the most environmentally efficient production method, whether to use machining processes or to use forming processes, for a particular part can be determined.

C.2.1.2 Evaluation is based on specific environmental data

Specific manufacturing system elements can be evaluated by referring to available specific data and provide a precise evaluation of environmental influence in addition to productivity and cost, for better machines or equipment selection to advance environmentally conscious production.

C.2.2 Environmental evaluation of products during production

C.2.2.1 General

For producing specific target products, it is required to select appropriate factories or manufacturing systems. It could be quite different, in terms of environmental evaluation, whether to produce them in domestic factories or in foreign factories.

There could be two cases, as described in C.2.2.2 and C.2.2.3.

C.2.2.2 Evaluation is based on general environmental data

General evaluation of environmental influence for a certain product at the stage of manufacturing can be done, with the result used for generic comparison of manufacturing stage influence for various products of the same or similar category.

C.2.2.3 Evaluation is based on specific environmental data

When producing specific target products, different factory locations, e.g. domestic or foreign, proximity to raw materials or markets, may yield different environmental evaluation for appropriately selected factories or manufacturing systems.

C.2.3 Environmental evaluation of manufacturing system improvements

In practice, especially for discrete products/parts manufacturing, manufacturing system configuration or individual manufacturing equipment configuration continuous improvements lead to better system performance. Consequently, a new environmental evaluation can also reveal an improvement in environmental efficiency.

C.3 Activities through manufacturing system life history (View-2)

C.3.1 General

ISO 20140 can be used for various process/activities, as analysed in Annex A.

C.3.2 Bench marking of environmental influence

ISO 20140 can be used for following bench marking of environmental influence (A42, decomposed into A421, A422 and A423):

— of an actual individual manufacturing system with a generic manufacturing system;

— between different manufacturing systems for producing the same product.

C.3.3 Alternative studies of environmental influence

ISO 20140 can be used for following alternative studies of environmental influence:

— for improvement of current manufacturing process (A121, A122 and A124);

— for planning for reconfiguring the current manufacturing system (A21);

  — to improve the current manufacturing system;

  — to adapt with the change of mass of product or product mix, including the study of reuse/recycle/disposal of current manufacturing equipment (A5);

— for planning a new manufacturing system (A21) for products, including the study of reuse of current manufacturing equipment (A5).

C.3.4 Comparison of manufacturing system component supplier's ECD

ISO 20140 can be used during alternative studies of environmental influence, as listed in C.2.2, for comparing the manufacturing system component supplier's ECD, which are based on a common evaluation method.

C.3.5 Allocating environmental targets down the manufacturing hierarchy

ISO 20140 can be used for setting the top level target of environmental improvement and break them down to the shop floor and individual manufacturing equipment environmental improving targets, by capturing and reporting the actual status, providing the historical review (A42, decomposed into A421, A422 and A423), and applying the above bench marking and/or alternative study results.

C.3.6 Monitoring and improvement of the shop floor operations

ISO 20140 can be used for monitoring and improvement of the shop floor operations, by visualizing the actual status of environmental influence (A42, decomposed into A421, A422 and A423).

Annex D
(informative)

Input to/output from unit process

The inputs to and outputs from the unit process are summarized in Table D.1.

Table D.1 — Input to/output from unit process

Category of environmental influence	Manufacturing system		Manufacturing system situation	Input to/output from unit process	
	Manufacturing equipment	Manufacturing support system		Input	Output
Direct influence	: Manufacturing equipment direct operation for producing product				
(Horizontal axis in Figure 4)	✓	n.a.	Manufacturing equipment direct operation for producing product	Material	Product
	✓	n.a.		Other resource for direct operation	Reusable material & energy Waste & release out of direct operation
Indirect influence					
(The left pair of vertical axis in Figure 4)	: Manufacturing equipment in indirect mode				
	✓	n.a.	Manufacturing equipment in idle/standby mode	Other resource for manufacturing equipment in idle/standby mode	Waste & release out of manufacturing equipment in idle/standby mode
	✓	n.a.	Manufacturing equipment maintenance	Other resource for manufacturing equipment maintenance	Waste & release out of manufacturing equipment maintenance
(The centre pair of vertical axis in Figure 4)	: Manufacturing support system operation & maintenance				
	n.a.	✓	Manufacturing support system operation	Other resource for manufacturing support system operation	Waste & release out of manufacturing support system operation
	n.a.	✓	Manufacturing support system maintenance	Other resource for manufacturing support system maintenance	Waste & release out of manufacturing support system maintenance
CRR influence	: Manufacturing system construction, reconfiguration & retirement				
(The right pair of vertical axis in Figure 4)	✓	✓	Manufacturing system construction/ reconfiguration	Other resource for manufacturing system construction/reconfiguration	Waste & release out of manufacturing system construction/reconfiguration
				Environmental influence footprint of employed system component	n.a.
				Residual CRR influence, residual system value of reused system component	n.a.
	✓	✓	Manufacturing system retirement	Other resource for manufacturing system retirement	Waste & release out of manufacturing system retirement
				n.a.	Residual CRR influence, Residual system value of reusable, recyclable and disposed system component

Annex E
(informative)

Conformance classes of ISO 20140

E.1 Classification of the conformance classes

Conformance classes of ISO 20140 shall be classified by the combination of View 1 and View 2, as shown in Table E.1.

Each view shall be decomposed as follows:

— View 1: Environmental influence of concern:
  — Conformance Class 1.a (CC 1.a): Energy efficiency;
  — Conformance Class 2.a (CC 2.a): Energy efficiency and material efficiency;
  — Conformance Class 3.a (CC 3.a): Energy efficiency, material efficiency and hazardous substance;
  — Conformance Class 4.a (CC 4.a): Energy efficiency, material efficiency, hazardous substance and other aspects/substance;
— View 2: Environmental influence across the manufacturing system life history:
  — Conformance Class b.1 (CC b.1): Direct influence;
  — Conformance Class b.2 (CC b.2): Direct influence and indirect influence;
  — Conformance Class b.3 (CC b.3): Direct influence, indirect influence and CRR influence.

Table E.1 — Classification of conformance classes of ISO 20140

			View 2: Environmental influence across the manufacturing system life history (MSLH)		
			Direct influence	Direct influence and indirect influence	Direct influence, indirect influence and CRR influence
			CC b.1	CC b.2	CC b.3
View 1: Environmental influence of concern	Energy efficiency	CC 1.a	CC 1.1	CC 1.2	CC 1.3
	Energy efficiency and material efficiency	CC 2.a	CC 2.1	CC 2.2	CC 2.3
	Energy efficiency, material efficiency and hazardous substance	CC 3.a	CC 3.1	CC 3.2	CC 3.3
	Energy efficiency material efficiency, hazardous substance and other aspects/ substance	CC 4.a	CC 4.1	CC 4.2	CC 4.3