5 Integrated Controlling Based on Material and Energy Flow Analysis – A Case Study in Foundry Industries

Christoph Lange, André Kuchenbuch

Christoph Lange, Chair of Environmental Management and Controlling,
University of Duisburg-Essen, Germany
E-Mail: c.lange@uni-essen.de

André Kuchenbuch, Chair of Environmental Management and Controlling,
University of Duisburg-Essen, BehrHella Thermocontrol GmbH, Lippstadt,
Germany
E-Mail: a.kuchenbuch@cityweb.de

5.1 Introduction

The basis of the following paper is the project entitled "Development of an Integrated Controlling Concept Based on a Process-oriented Costing System with Regard to Optimised Material and Energy Flows in Iron, Steel and Malleable Iron Foundries" (INPROCESS), sponsored by the *Bundesministerium für Bildung und Forschung* (German Federal Ministry of Education and Research). The project is an interdisciplinary research project that aims at creating practically-oriented controlling tools in a sustainable development context.

5.1.1 The INPROCESS Project

Project Members

In addition to the core project team, project partners comprise the German Foundry Association, the Chair of Environmental Management and Controlling at the University of Duisburg-Essen/ Germany (Essen Campus), the German Institute of Foundry Technology, the ARÖW – Gesellschaft für Arbeits-, Reorganisations- und Ökologische Wirtschaftsberatung mbH (a business consultants network specialised in occupational, reorganisation and ecological consulting) and nine foundries, in which the content-related focuses of the project (material flow analyses, process-oriented environmental activity based costing, integrated performance indicator systems) were examined in the form of case studies.[1]

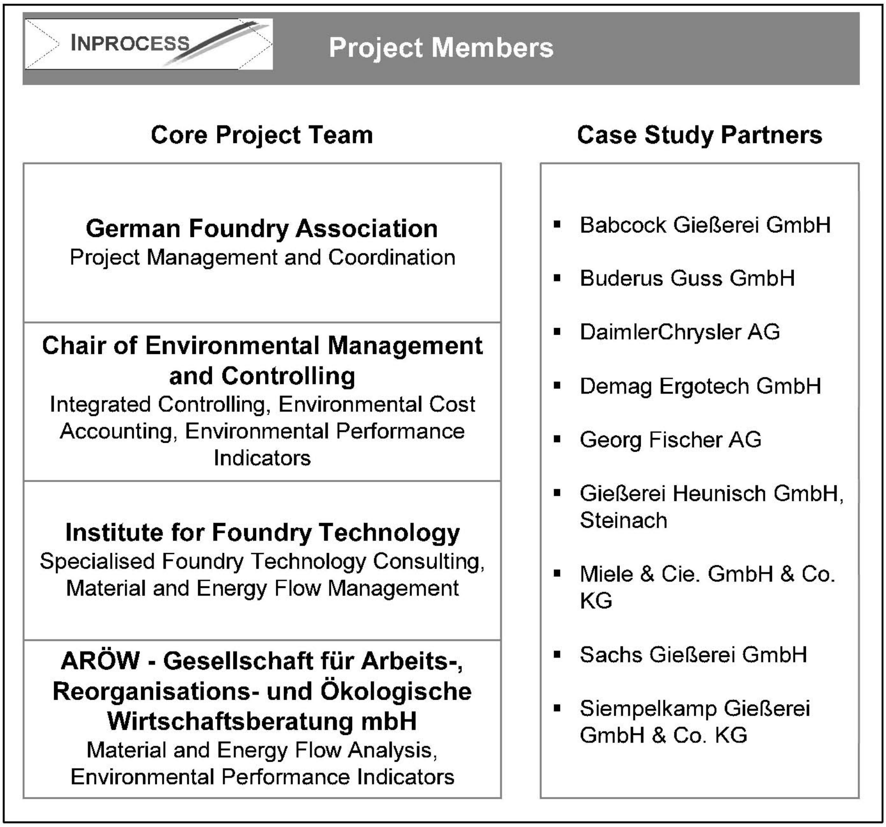

Fig. 5.1. Inprocess project members[2]

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[1] See Lange et al. 2002; Lange and Kuchenbuch 2003a, p. 26 et seq.; Kuchenbuch et al. 2004, pp. 24-29

[2] Source: Lange and Kuchenbuch 2003, p. 27, Remarks: The authors would like to thank all the participants of the INPROCESS project, particularly the co-operating practice partners, without whom the project results would not have been possible.

Presentation of the Problem

In the face of increasing environmental pollution, scarcity of resources and an intensified competitive atmosphere, foundries are being challenged by increasingly dynamic structures and processes:

- Factors related to the environment are continually gaining in importance, be they linked to the obligation to meet legal stipulated requirements or to voluntary compliance with specific threshold values for the purpose of boosting the company's image or in anticipation of future developments, etc.
- The pressure to reduce costs makes it essential for the foundries to optimise their material and energy flows.
- To this end, both cost-effectiveness as well as ecological efficiency have to be ensured and monitorable.

However, the required co-ordination, planning and controlling run into difficulties, since conventional costing and controlling systems do not allow any integrated control of the various, thematically different areas.

Objective

The objective of this project is to unite, for the benefit of the sector, two essential task areas within the scope of decisions that are environmentally related and based on the principle of sustainable management:

1. Process-oriented controlling based on material flow and energy management, comprising the following tasks:
   - Identification, recording and documentation of the material and energy flows
   - Identification of the savings potentials for the most significant resource consumption areas
   - Outline and description of the measures for implementing the savings potentials

The resultant findings and identified measures for reducing the usage of resources are prepared in a way that enables the foundries to independently realise corresponding improvements. To support them in this, extensive guidelines will be created within the scope of the project.

2. Derivation of a requirements profile for the expansion of costing systems in regards to environmental protection, allowing for optimised material and energy flows as a component of integrated controlling.

On the basis of the results of the analyses, the aforementioned guidelines will be provided for the purpose of planning, controlling and monitoring both the economic and ecological objectives within the framework of an integrated controlling system.

5.1.2 Basics of Integrated Controlling

Constantly accelerating changes on the markets associated with a growing segmentation of customer groups, rising innovation rates and accordingly shorter product life cycles result in a rapid change in the competitive environment of companies. For the most part, only those companies that offer customised, exceptionally innovative, qualitatively high-quality and environmentally-friendly products and services produced with the use of few resources can remain competitive over the long-term.[3] Foundries also have to address these changes and must gear their management and performance processes towards market demands.

This necessitates a broadening of the focus of the primarily company-internal – in part also only accounting-oriented – approach to controlling by incorporating perspectives that extend beyond the company boundaries.[4] In addition to the expansion of this approach, an orientation on the guiding principle of sustainable development requires the creation of a multi-criteria objective system that comprises not only economic, but ecological and social objectives as well.

In the context of the conducted project, integrated controlling can be defined as a management subprocess, essentially pertaining to the (company-internal) business processes as well as the (inter-company) value-added chain, for co-ordinating management activities on all decision-making levels of the company. Controlling should thus be primarily geared towards the company-internal interfaces (e.g. within and between business processes, departments and divisions).[5] Furthermore, it should increasingly provide the information that is requested by those stakeholders (e.g. customers, authorities, suppliers, employees, residents) who are deemed strategically relevant.

To implement the concept of integrated controlling, the following potential expansion stages can be derived.[6]

[3] See Schaefer 2001, p. 1

[4] See Lange et al. 2001, p. 75; Lange and Martensen 2003

[5] See Lange et al. 2001, p. 75

[6] For more detailed information on the concept of integrated controlling see Lange et al. 2001, Schaefer 2001; Daldrup 2002, pp. 9-32.

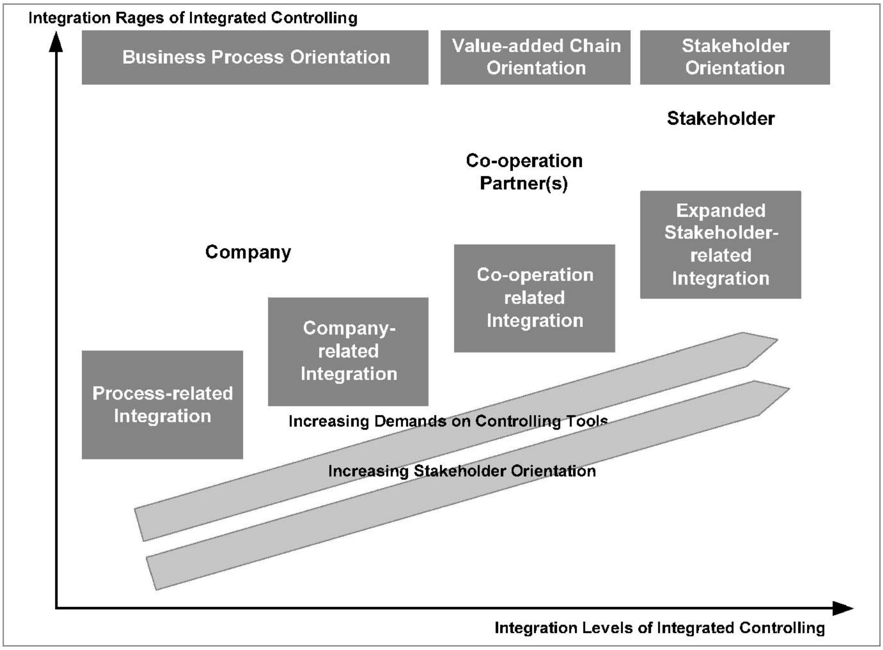

Fig. 5.2. Expansion stages of integrated controlling[7]

As an example, the following table illustrates the effects that the different expansion stages of integrated controlling have on the company's objective system.

Table 5.1. Examples of the expansion stages of integrated controlling[8]

Process and Company-related Integration	Co-operation-related Integration	Expanded Stakeholder-related Integration
• Expansion of objective system via the addition of requirements of e.g. employees, management	• Expansion of objective system via the addition of requirements of e.g. customers, suppliers	• Expansion of objective system via the addition of requirements of e.g. residents, authorities

[7] Source: Lange and Kuchenbuch 2003, p. 27
[8] Source: Lange and Kuchenbuch 2003, p. 27; Kuchenbuch et al. 2004, p. 25

Table 5.1. (Cont.)

• Possible objectives: identification of cost reduction potentials, increase in transparency regarding material and energy flows, substitution of noxious materials	• Possible objectives: establishment of development partnerships, reduction in product development times	• Possible objectives: reduction of noise and dust emissions

The objective of integrated controlling can thus be seen as the support of management in the formulation and communication of a company policy that addresses the interests of preferably all stakeholders deemed to be strategically relevant. This also includes the provision of information that enables all management levels to implement a sustainable company management, with process integration at the forefront of this contribution.

5.2 Phase Model for Introducing Integrated Controlling in Foundry Companies

Based on the above-mentioned necessity for a re-orientation of controlling, a phase model for the foundry sector was developed within the scope of the underlying research project. The phase model was intended to serve as a means of orientation for the companies to assist them in adapting their internal information procurement and decision-making support processes to the changed market conditions. In this context, it was ensured that the recommended tools were based on information and tools already existing in the foundries, in order to keep reorganisation expenses and efforts as low as possible and thus increase acceptance of the proposed concept.

The following diagram provides an overview of the phases of the model:[9]

[9] For more on the specific content of the individual tools/ phases of this model, see Kuchenbuch et al. 2003; Lange and Kuchenbuch 2003; Lange and Kuchenbuch 2003a; Lange et al. 2003.

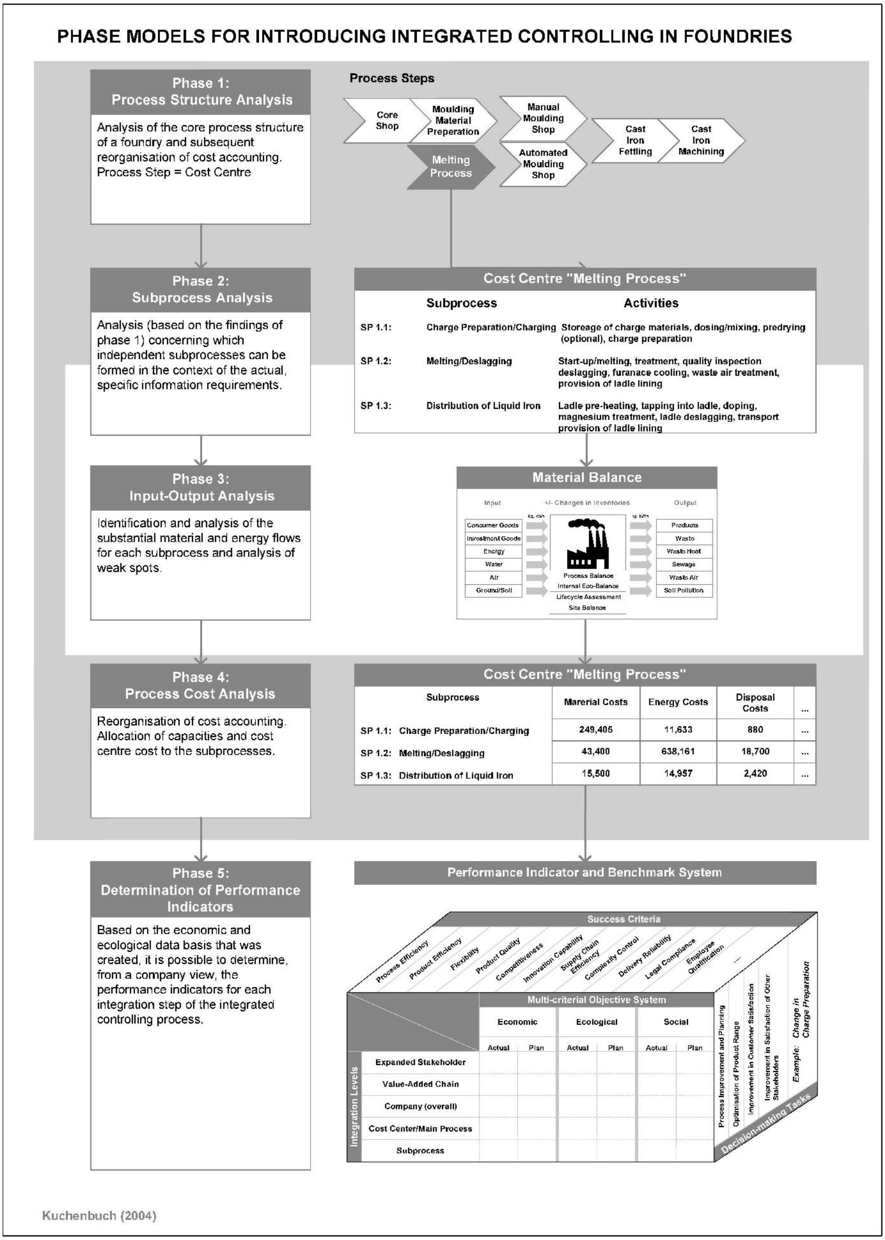

Fig. 5.3. Phase model for introducing integrated controlling in foundries[10]

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[10] Source: Kuchenbuch 2004; also see Lange and Kuchenbuch 2003, p. 32

5.2.1 Phase 0: Information Requirements Analysis

The starting point for the information requirements analysis is "stakeholder scanning"[11], a tool system for identifying the interests of potentially strategically relevant interaction partners on a company, co-operation and/ or (expanded) stakeholder level. It comprises identifying and characterising the potential market and non-market related stakeholder groups as well as the analysis, forecasting and evaluation of the interests and expectations concerning the achievement of objectives on the part of these stakeholders with regards to the company.
In the project conducted, the following stakeholder groups were identified as being particularly relevant in terms of strategic factors:[12]

Table 5.2. Stakeholders of strategic relevance for foundries

	Stakeholders	Potential Interests/ Requirements
Internal	Management	• Power, influence, prestige (regarding ecological aspects as well) • Development/ realisation of own ideas/ capabilities
	Employees	• Income (workplace/ job) • Environment-oriented workplace • Ecological image of company • Social security and contacts
	Shareholders	• Preservation of invested capital; return and appreciation on invested capital • Inclusion of environmental aspects in due diligence reviews • Opportunities for participation

[11] See Horváth 2003, p. 401 et seq. and the literature references provided there
[12] See Dyllick 1984, p. 75; Lange et al. 2001, pp. 52-88; Pohl 2001, pp. 59-63

Table 5.2. (Cont.)

	Stakeholders	Potential Interests/Requirements
External	Residents	• As a rule, directly affected by noise and odour emissions.
	Authorities	• Supervisory body for compliance with immission limits and regulations related to environmental protection • Commissioning of regulated equipment, plants and facilities subject to approval • Inspection of MAK (maximum concentrations at the workplace) values.
	Customers	• Automobile manufacturers make a variety of demands with respect to the ecological composition and impact of products • Inclusion of ecological factors in the criteria for selecting suppliers
	Banks	• Consideration of ecological risks when granting loans • Possible damage to bank's image if a customer appears or is perceived as being harmful to the environment • Inclusion of environmental factors when conducting ratings
	Insurance Companies	• Consideration of ecological risks in the course of incident analyses • More favourable conditions in regards to employer's liability insurance (product risk) and the German environmental liability law (facility liability) for companies with active environmental protection policies/ environmental protection management

Based on the requirements of the relevant stakeholders and the company objectives derived from them, the analysis of the significant economic, ecological and social decision-making tasks to be met by the management of a foundry, as well as the information requirements associated with them, forms the starting point of Phase 0. Therefore, it is important to expressly point out here that the definition of decision-making tasks is explicitly not under the responsibility of Controlling, but rather incumbent on the company management.

5.2.2 Phase 1: Process Structure Analysis

The goal of the process structure analysis is to identify a company's value-adding business processes. This analysis creates the organisational basis for determining the material and energy flows, for reorganising the costing and thus for integrating information relevant to decision-making onto identical reference objects. In the first phase of the INPROCESS PROJECT, the process structures of the participating foundries were recorded and documented and the value-adding core processes of a foundry were identified by way of derivation. While the individual subprocesses can vary depending on the product spectrum and product process, the following seven process steps can be considered as pivotal to the net product of sand foundries.[13]

- Core Shop
- Moulding Material Preparation
- Manual Moulding Shop
- Automated Moulding Shop
- Melting Process
- Cast Iron Fettling
- Cast Iron Machining

From a costing viewpoint, the identified process structures described above represent the minimum manifestation of the main processes to be generated. Whether or not additional cost centres or sub-cost centres (for the direct production area) have to be set up depends on the respective information requirements. Thus, e.g., it is conceivable that the "melting process" process step can be further subdivided into "charge preparation" and "melting plant" process step. This would then be practical if, within the melting process, a large number of melting units are bundled, which also vary in their dimensions and melt various liquid iron qualities. In this case, the integration into one single cost centre would result in a loss of information due to the aggregation. The number of cost centres to be formed is thus dependent on the respective internal/ operational context.

In view of the decision-making orientation underlying the integrated controlling method, however, it is important that the cost centre structure be aligned along the internal value-added chain, to ensure that the integration of material, energy and cost-based data onto identical reference objects is subsequently successful.[14]

5.2.3 Phase 2: Subprocess Analysis

Based on the results of the process structure analysis, the subprocesses then have to be identified for each defined process step within each respective cost centre, using an iterative reconciliation process between material and energy flow accounting and process-oriented costing. It must

[13] Due it its relative independence and low material and energy expenditure, the model making shop is not taken into consideration here.

[14] See Kuchenbuch et al. 2003, p. 36; Lange and Kuchenbuch 2003, p. 30

be ensured that only those subprocesses are defined for which both an activity-based cost allocation and a determination of the material and energy flows can be carried out based on economic factors.

The procedure: first, the tasks carried out within a cost centre are determined. In a second step, the individual tasks are condensed into homogeneous "task bundles", which are called subprocesses in the following. These subprocesses represent the integration level or reference objects for which both the material and energy flows as well as the cost information have to be determined.

5.2.4 Phase 3: Input-Output Analysis

The central point of the material and energy flow accounting is the preparation of a complete and consistent input-output analysis. Taking into account the production-specific relationships between resource utilisation, products, waste and emissions, all the inputs and outputs needed for covering the information requirements are determined for the defined subprocesses. To this end, the available data on all company levels first has to be collected and a systematic analysis then conducted to verify completeness and consistency. Any missing data has to be supplemented by means of measurements, calculations or assumptions.[15] The following chart illustrates a checklist indicating the essential areas for which data has to be collected on the subprocess level of a foundry.

[15] See Kuchenbuch et al. 2003, p. 36

INPROCESS **INPUT-OUTPUT ANALYSIS FOR FOUNDRIES**

SP 1: Charge Preparation/Charging			
Input		**Output**	
▪ Crude Iron	xxxx t	▪ Charged Material	xxxx t
▪ Steel Scrap/Scrap Iron	xxxx t	▪ Dust	xxxx t
▪ Recycling Material	xxxx t	▪ Noise	xxxx db(A)
▪ Alloying Additions	xxxx t	▪ Waste	xxxx kWh
▪ Slag Binder	xxxx t	Heat	
▪ Energy	xxxx kWh	▪ Land Consumption	xxxx m^2

Equipment/Facilities

- Bunker/Boxes/Land
- Crane/Scales/Formula Management/Analytics
- Drying Furnace (optional)
- Transport System/Charging Device
  Extractor (Drying Furnace/Shop)

Required Human Resources	Worker Years at Specified Capacity
▪ Production Employees	xxx
▪ Managerial Employees	xxx
▪ Temporary Employees	

Transformation Rules

- Material: n/a
- Energetic: $E_{in} = x * E_{Fe} + (1 - x) * E_{diss}$ (Energy Equation for Drying Furnace)

  with:
  E_{in} = Energy Input
  x = Factor
  E_{Fe} = Energy stored in iron
  E_{diss} = Energy Dissipation

Fig. 5.4. Example of an input-output analysis[16]

The data that has thus been determined and checked for consistency can be visualised in a Sankey Diagram. The following diagram provides an example of the possible material flow of a melting process:

[16] Source: Kuchenbuch et al. 2003, p. 36

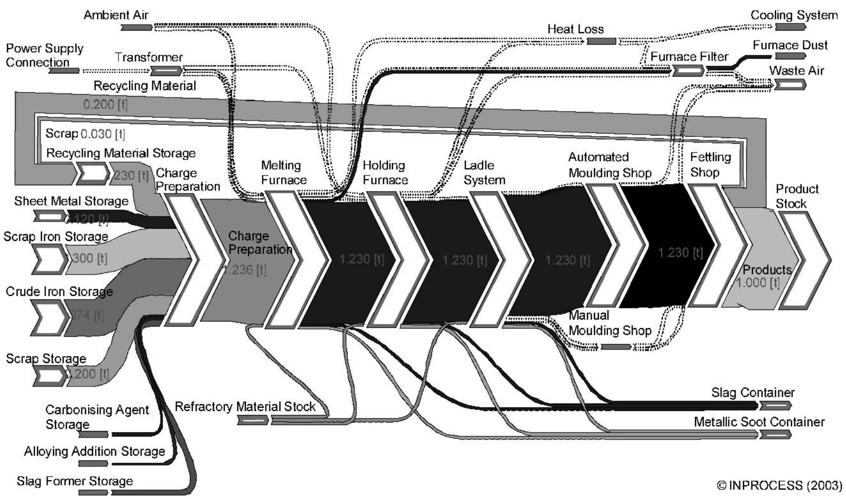

Fig. 5.5. Sankey diagram of the material flows for the melting operation core process.[17]

As the Sankey Diagram shows, the moulding shop and cast iron machining/ fettling shop are core processes which should be allowed for in the analysis of the melting process, since they serve to assist in the integrated analysis of the material flows (recycling material and scrap) (Rebhan 1999; Rebhan 2000). To obtain indicators about weak spots and optimisation potentials, it is practical to derive indices from this data that can be used for internal and external benchmarking. Once the starting points for the optimisation measures have been identified, their technical and organisational feasibility has to be analysed. The effects of these measures on the material and energy flows within the company, and – in conjunction with the corresponding broadening of the focus of the examination – on a cross-company basis as well, can subsequently be determined along the entire value-added chain. Utilising the MEAS-System[18] in the foundries participating in the INPROCESS project, the project team succeeded in compiling a series of starting points for optimisation measures. Furthermore, prior to actually implementing the measures, deployment of the AUDIT software simulated the effects on the material and energy flows as well as the costs associated with them.

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[17] Reference quantity: one ton of machine moulded sound castings (Source: Kuchenbuch et al. 2003, p. 37)

[18] Meas = Material and Energy Analysis System.

5.2.5 Phase 4: Process Cost Analysis

Concept of Environmental Activity-based Costing

Described in the following, the approach of a process-oriented environmental activity-based costing method for the foundry industry is conceptually based on the basic idea of activity-based costing (formulated in the USA).[19] Activity-based costing is a process-oriented costing system that focuses on a transparent and (to the greatest extent possible) activity-based cost allocation for the direct performance areas of a company. Within the scope of the INPROCESS project, this system was further developed with respect to environmental aspects. The central point is the integration of material and energy data with cost-oriented information to identical objects under consideration. To this end, the subprocesses of each cost centre, which function as integration levels, have to be defined in close co-ordination with the material and energy flow accounting.

The approach is distinguished by the following characteristics:

- Process orientation in cost centre and cost unit accounting
- Usage of cost concept(s) augmented by environmental aspects
- Differentiated identification of costs relevant to decision-making and the environment as well as the essential material and energy flows of each subprocess[20]
- Focus on the direct production areas
- Separate (informal) identification of the recycling material costs for each subprocess
- Extensive use of reference quantities from the material and energy flow accounting
- Conceptualised as parallel accounting
- Documentation/ recording of environmental impact solely in the form of internalised costs and completely documented material and energy flows, i.e. no analysis of external effects.

As has already been described in detail in the process-structure analysis section, it is necessary to create cost centres along the internal value-added chain of a foundry, as that is the only way to ensure that the material and energy data as well as the process-oriented cost data are allocated to identical reference objects and thus guarantee a consistent data basis for the

[19] See Miller and Vollmann 1985; Pfohl and Stölzle 1991; Coenenberg 2003, pp. 205-230; Horváth 2003, 543 et seq.; Schweitzer and Küpper 2003, pp. 345-381

[20] For more on the differentiated identification of material and energy flows, see Kuchenbuch et al. 2003.

performance indicator-supported provision of information via integrated controlling. The precise implementation of the environmental activity-based costing approach will be explained in more depth in the following sections.

Cost Element Accounting

Due to its concept as a parallel accounting method, environmental activity-based costing is based on the existing cost element structure of conventional costing accounting. Since not all cost elements[21] for a foundry – in terms of both economic and ecological aspects – carry the same importance, the cost elements should be aggregated into basic cost element groups. In addition to condensing the information, the advantage of such a process is that it also reduces complexity, which is important for the acceptance of the costing method. On the basis of the concept of environmental costs[22] and the information requirements of integrated controlling, we recommend creating the following cost element groups and disclosing them in both the cost centre accounting (per subprocess) and the cost unit accounting (per product):

- Material Costs
- Energy Costs
- Personnel Costs
- Internal Performance
- Calculatory Capital Costs
- Maintenance Costs
- Waste Disposal Costs
- Allocation 1: General
- Allocation 2: Administration and Sales
- Allocation 3: Production Support

Furthermore, a review should be conducted, taking into account the specific internal decision-making situation and information requirements, to determine whether it is necessary to differentiate each cost element group according to conventional and environmentally relevant costs.

Cost Centre Accounting

The structural design of the cost centre accounting is based on the results of the subprocess analysis.[23] Here, the subprocesses for which process-oriented cost data now has to be ascertained were determined for each cost centre. Against this background, the cost centre costs, which can be taken from the conventional costing and distributed according to the cost ele-

[21] See DGV 1996, pp. 23-26

[22] For more on the concept of environmental costs, see Lange and Kuchenbuch 2003a, p. 24 et seq.

[23] See Kuchenbuch et al. 2003, p. 36 et seq.

ment groups described above, have to be allocated to the defined subprocesses. For this, the process cost analysis should include a check to determine, for each cost element, how to allocate them to the subprocesses. It should be noted here that the effort involved in collecting data for the allocation key is justifiably proportionate to the required accuracy. The determination of possible allocation keys is elaborated on in the following, using the example of the *Energy Cost* element:

Basically, energy costs can then be best allocated if the consumption volume of each consuming unit is recorded via a counter or meter. From a costing viewpoint, such an allocation key would be the most suitable and thus is assigned priority 1. However, in practice, this process approach leads to insignificant difficulties. It is associated with considerable expense, since each unit has to be equipped with a meter/ counter; moreover, it has to be ensured that the meter/ counter readings are read for each reporting or accounting period and forwarded to the Costing. Furthermore the installation of meters/ counters for large units is practical and feasible, while a separate meter/ counter for the lighting of a cost centre hardly seems realisable in terms of practical considerations. If continuous consumption measurements are not possible or practical, the next option is to rely on reference and target values (priority 2). These values can be determined on the basis on the technical consumption data. Thus, e.g,. for a holding furnace, such a target value can be determined by means of the installed capacity and the elapsed operating hours. The third option to be considered is a proportional distribution based on empirical values (priority 3). This process usually leads to quick results, but is characterised by a very high degree of inaccuracy and subjectivity. As a starting point for a more precise analysis, however, it does appear quite suitable.

In the practical implementation of this approach, therefore, a mix of the respective data collection options should always be employed. It is thus expected that particularly important equipment (e.g. a melting furnace) is equipped with a meter/ counter for internal monitoring purposes, whereas other units (e.g. suction apparatuses) are controlled via reference and target values or via proportional allocation based on empirical values (e.g. hall lighting). In regards to the operational dependency of the costs and the issue of reduction associated with it, the variable and fixed cost elements have to be determined, as far as possible, for each cost element group. This information is important in terms of decision-making situations, e.g. in connection with break-even analyses, and provides information about the temporal reduction of the costs. To ensure a realistic evaluation of the both the recycling material and the scrap quantity, a separate recognition and cost-related evaluation should be carried out along the lines of flow cost accounting.[24] To this end, the total costs of each subprocess – different-

[24] See Gay 1998; LfU (Landesamt für Umweltschutz/ State Environmental Protection Agency) 1999; Strobel and Wagner 1999

tiated according to the aforementioned cost element groups – have to be allocated to the "sound castings" as well as the recycling material and scrap. An allocation is carried out in dependence on the reference quantity, via which the process costs are also allocated to the products.

Cost Unit Accounting

Within the scope of the cost unit accounting, it must then be determined as to which product will utilise what process (main process or subprocess) and to what extent. To this end, depending on the desired accuracy level, there is the option of allocating the costs originated by the subprocesses via a common reference quantity per cost centre or a reference quantity per subprocess. Here as well, it must be noted that with a rising number of reference quantities, the effort involved in collecting the data also increases and the complexity mounts. By way of illustration, it should be assumed that the process costs of the melting process cost centre example are allocated to the cost units via the standardised *product weight* reference quantity. In a first step, the determination must be made with respect to what extent an individual product has utilised the reference quantity. For this, the specific weight of an individual product is multiplied with its output during the period and then this sum is compared in proportion to the total weight of all products. The thus determined percentage or equivalent figure is then used for allocating the subprocess costs to the products. In a second step, the subprocess costs for each product are calculated by multiplying the subprocess costs with this equivalent figure; a subsequent division by the output of this product determines the unit costs.

5.2.6 Phase 5: Performance Indicator-supported Provision of Information

Consistent and systematic implementation of the first four phases (process structure, subprocess, input/ output and process costs analyses) of the model for introducing integrated controlling into foundries creates a data basis which, from a company or corporate standpoint, enables a far-reaching *complete* provision of information for the respective stake-holders.[25] Based on this data, a performance indicator model is created in Phase 5, which is intended to assist the management of a foundry in making objective-oriented decisions in terms of controlling, particularly in

[25] See Lange and Kuchenbuch 2003, p. 30 et seq.

order to exploit potentials for saving costs and resources.[26] In light of the respective information requirements as well as the expansion stages of integrated controlling, a performance indicator system is needed that ensures the provision of information pertaining to all relevant stakeholders. However, it must be taken into consideration that not only those performance indicators that can be derived from the material, energy and cost-oriented data should be used. Furthermore, the main task is to broaden the scope of consideration as well as map such information in the form of performance indicators, which – in the sense of DIN 14031 – can generally be termed environmental management and environmental condition indicators.[27] When developing this model, the objective is thus to create a flexible system based on the data basis; a system which, depending on the information requirements of the management, can provide data relevant to decision-making in the form of performance indicators. For this reason, a rigid system is not presented in the following, but rather an open system that ensures the flexible provision of information. Based on these general conditions, the following performance indicator systematic is recommended:

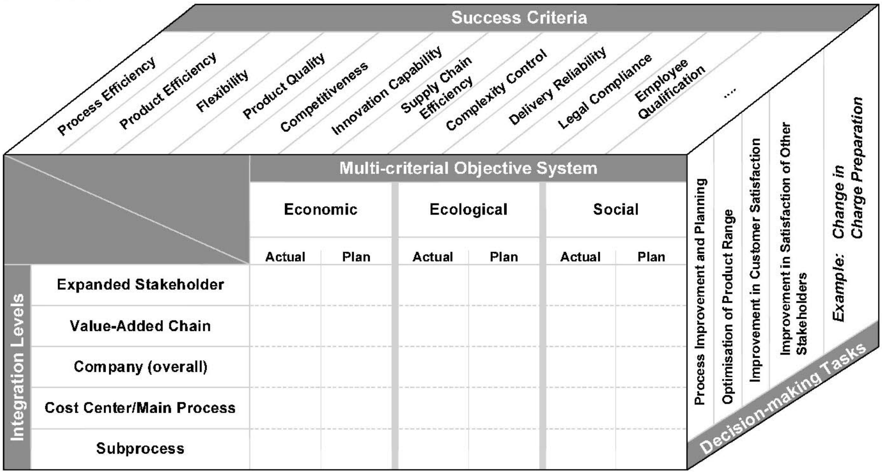

Fig. 5.6. Multidimensional performance indicator model of integrated controlling[28]

[26] See Lange et al. 2003, p. 32

[27] See Lange et al 2003a, pp. 217-221

[28] Source: Author. For more on this content, see Kuchenbuch et al. 2004, p. 27. Note: The "Decision-making Tasks" dimension contains a column titled 'Example: Changes in Charge Preparation Accounting'. This refers to an example used in Chapter 3 for the purpose of documenting the process sequence along the phase model.

The first starting point for creating and implementing the performance indicator model described above is to derive the most important decisions that have to be made by the management of a foundry. However, a mere analysis of the relevant decision-making tasks is usually not sufficient for determining specific indicators. Therefore, the essential success/ performance criteria have to be defined for each decision-making task. Table 5.12 (in Section 5.3.2) lists examples of possible success criteria for each of the three dimensions of sustainability (economy, ecology, social). Nevertheless, the question of what success criterion is significant for which decision-making task cannot be answered in general terms, but rather only in consideration of the specific company background. One or more indicators have to be determined for the operationalisation of each of these success criteria

By utilising the underlying process structure, the performance indicators can be generated on all levels of the process model (e.g. subprocess, main process, cost centre and company levels) and consolidated via the respective material-energy transformation[29] and/ or organisational aggregation rules. Other levels of consideration include the *value-added chain* and *expanded stakeholder levels* derived from the integration steps of integrated controlling.

The objective of using the performance indicators is to enable the evaluation of alternative system statuses. A comparison of system statuses can take the form of a period comparison, actual/target comparison or a system comparison conducted prior and subsequent to implementing technical-organisational measures. To this end, in the performance indicator system outlined here, ecological and, if applicable, social indicators are used in addition to the classical economic indicators (Reichmann 2001, pp. 51-112), thus creating the pre-requisite for sustainable company management (Kuchenbuch et al. 2004, p. 28). The generated indicators represent measuring points or sensors in companies that enable the documentation of changes and the provision of information regarding the reasons for the changes. A more detailed example of this is presented in Section 5.3.6.

[29] In the context of material flow accounting, 'transformation rules' are to be seen as the rules for calculating a specific output structure (horizontal data compression) from a given input structure and the associated data (e.g. originating from a system in a plant). In contrast, 'aggregation' refers to a vertical compression of data across various organisational levels.

5.3 Case Study: Model Foundry

The model foundry was developed within the scope of the BMBF INPROCESS project with the intention of evaluating the project results for the focuses of the integrated controlling project, the process-oriented environmental activity-based costing as well as the material and energy flow accounting. The goal was to find a foundry layout that depicted all the significant findings of the case studies[30] conducted in the INPROCESS project. Moreover, the model foundry served as an illustrative example for the industry guidelines. By way of these guidelines, the results of the project were distributed to the industry via German Foundry Association.

The structures, material and energy flows[31], as well as the costs associated therein, that are documented in the following represent the attempt to depict the complexity and heterogeneity of the approx. 250 foundries in the Federal Republic of Germany in one model. The project team was consequently faced with the challenge of generalising the various process variant options, particularly in regards to the melting units, moulding processes, company sizes, casting qualities, etc., and integrating them into the model in a way that would enable the description of a as large as possible part of the actually existing foundries.

According to both the INPROCESS team and the participating experts from the foundries, both the cost data described as well as the material and energy flows depict a realistic representation of the production structures and the production range. However, it should be pointed out here that a model must always inevitably be a simplified version of the real thing.

[30] In the project, a total of nine case studies were conducted in the participating foundries, with different thematic focuses. On the one hand, the respective focuses were selected because they were more relevant to the respective company, and on the other, the selection ensured that all essential issues relevant to the research project were addressed. This allowed the project team to work out solution approaches for specific questions and make these findings available to the other foundries in a general form within the framework of the model foundry.

[31] Here, we would like to thank all the employees of the participating project partners (Institut für Gießereitechnik, Düsseldorf/Germany; Aröw – Gesellschaft für Arbeits-, Reorganisations- und Ökologische Wirtschaftsberatung mbH, Duisburg/Germany) for their work and contribution.

5.3.1 Basic Structure of the Model Foundry

The Guss GmbH foundry is integrated into a mechanical engineering company as a 100% subsidiary. The company is an internal supplier of compressor pumps, which it manufactures in five production series. The product spectrum comprises small heating water pumps up to large feed pumps for waste water, sludge and oil. The largest piece of equipment produced is a turbo-compressor weighing approx. eleven tons. Each of these pumps consists of an upper and lower section, suction flange, motor flange as well as an impeller. Thus, the production range includes a total of 25 casting parts, which, depending on the part to be manufactured, are produced in two casting qualities (grey and spheroidal graphite cast iron).[32] The casting parts are mechanically machined and varnished by the company's in-house departments. i.e. in the mechanical engineering department. Guss GmbH is internally divided into the following departments:

- Management/ Administration
- Purchasing, Engineering and Design, Sales, Shipping, Plant Security and Safety
- Melting Shop (incl. delivery, charge preparation, treatment and processing, ladle system)
- Manual moulding shop with two mixers for furan resin-bonded sand
- Automated moulding shop (incl. bentonite-bonded sand and coldbox cores)
- Fettling Shop (incl. manual fettling stations, blasting chamber and overhead conveyor blasting unit)
- Core Shop
- Sand Treatment (incl. mixer and mechanical sand regeneration)
- Annealing Bay
- Maintenance
- Models are procured from a specialised supplier.

In the following, based on the information presented this far, the results of the process analysis will first be documented and then the recording of the respective material and energy flows as well as the corresponding cost data for each process will be described.

[32] This paper refrains from documenting the respective product formulas and process-related transformation rules; please refer to the final project report. See INPROCESS Final Report, Deutscher Gießereiverband (German Foundry Association) 2004.

5.3.2 Phase 0: Information Requirement Analysis

The departure point for the considerations is the decision-making tasks derived from the respective company objectives as well as the associated information requirements on the part of the management of a foundry. In this context, the following tasks play a particularly important role:

- process improvement and process planning,
- optimisation of product range,
- improvement in customer satisfaction, and
- improvement in the satisfaction of other stakeholders.

In order to be able to manage these tasks, the most significant, foundry-specific economic, ecological and social performance/ success criteria were elaborated in the course of the project; the criteria varied in their degree of importance, depending on the respective decision-making task. These criteria are described in the following table:

Table 5.3. Selected economic, ecological and social performance/ success criteria in foundries[33]

Economic Dimension	Ecological Dimension	Social Dimension
• Econ. Process Efficiency • Econ. Product Efficiency • Flexibility • Product Quality • Competitiveness • Innovation Capability • Efficiency of Supply Chain Management • Customer Relationship Management • Complexity Control • Delivery Reliability • Minimisation of Liability Risk	• Ecolog. Process Efficiency • Ecolog. Product Efficiency • Legal Compliance	• Company/ Corporate Image at the Location • Assurance of Workplaces • Occupational and Health Safety • Employee Qualification

In order to be able to illustrate the individual phases and tools by way of a homogeneous example, it is necessary to reduce the complexity. Based on the current trends on the raw materials markets, the following decision-making situations for the management of a foundry are assumed:

[33] Source: Kuchenbuch et al. 2004; VDG 2001, p. 40

Example: In 2004, the booming economic development, especially in China, caused a raw material shortage in the steel scrap sector. China's steel imports had increased by approx. 50% in the previous year, resulting in a corresponding doubling of the steel prices[34]. The resultant demand on the world market also led to a considerably lower supply of steel scrap in Europe and Germany, along with a higher market price associated with it. In view of these developments, many foundries are now faced with the question of how to respond to the steel scrap shortage. Accordingly, an examination should be conducted with respect to the possibility of how to substitute the steel scrap charge material with cast iron scrap without resulting in quality changes. To this end, the question of what effects such a change in the charge preparation will have and what indicators should be applied for the controlling needs to be addressed. The primary focus is thus to demonstrate how the integrated controlling tool can be utilised to provide the necessary data. This creates the prerequisite of transparently presenting the effects associated with the substitution process.

5.3.3 Phase 1: Process Structure Analysis

Based on the findings of Phase 0, the current organisational structure was documented as well as analysed and optimised within the scope of the process structure and subprocess analyses. The focus of attention here was particularly on the direct production area, i.e., to put it conversely, the administration and sales cost centres were not examined. The reason for this was first and foremost due to the fact that in the underlying research project, the significant material and energy flows as well as the development of a process-oriented environmental activity-based costing method were the subjects under examination.

As already shown in 5.2.2, at least seven value-adding core processes could be identified on the basis of the case studies conducted and the expert knowledge of the German Foundry Association and the German Institute of Foundry Technology. In regards to the cost accounting, this constitutes a minimum categorisation of the cost centres. Diverging from this categorisation, the following cost centres were created for the specific application case of the model foundry:

- CC 1: Melting Process
- CC 2: Manual Moulding Shop
- CC 3: Sand Regeneration
- CC 4: Automated Moulding Shop
- CC 5: Sand Treatment
- CC 6: Core Shop
- CC 7: Blasting Chamber
- CC 8: Blasting System
- CC 9: Fettling Shop
- CC 10: Annealing Bay

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[34] See www.weyland.at/index.php?id=198, version dated 07-06-2004.

5.3.4 Phase 2: Subprocess Analysis

After conducting the process structure analysis, the essential subprocesses within each of the model foundry's cost centres were identified. At this point, the previously conducted task analysis will not be described further.

The goal of the subprocess analysis is to combine all the tasks carried out within a cost centre into homogeneous bundles, called the "subprocesses". Furthermore, here, the suppositions should already be taken into account in regards to how the subprocesses can be combined into main processes within the scope of the environmental activity-based costing. The resultant structures then form the basis for the cost allocation to the reference objects. The following table provides an overview of the results of the subprocess analysis conducted for the model foundry.

Table 5.4. Subprocess analysis and main process allocation[35]

CC	SP No.	Subprocess Name	MP Allocation
CC 1 Melting Process	1.1	Charge Preparation/ Charging	1
	1.2	Melting/ Deslagging	1
	1.3	Distribution of Liquid Iron	1
CC 2 Manual Moulding Shop	2.1	Mould Making	2
	2.2	Mould Casting	70 % = 1 30 % = 2
	2.3	Cooling of Casting	2
CC 3 Sand Rege nera-tion	3.1	Unpacking	3
	3.2	Sand Regeneration	3
CC 4 Automated Moulding Shop	4.1	Mould Making/ Pouring	4
	4.2	Cooling of Casting	4
	4.3	Unpacking	4
CC 5 Sand Treat ment	5.1	Used Sand Treatment	5
	5.2	Treatment of Moulding Material	5
CC 6 Core Shop	6.1	Treatment of Moulding Material	6
	6.2	Core Making	6
	6.3	Finishing/ Drying	6

[35] Source: Kuchenbuch 2004

Table 5.4. (Cont.)

CC 7 Blasting Chamber	7.1	Blasting	7
	7.2	Treatment of Blasting Agent	7
CC 8 Blasting System	8.1	Blasting	7
	8.2	Treatment of Blasting Agent	7
CC 9 Fettling Shop	9.1	Handling of Recycling Materials	8
	9.2	Fettling MC	8
	9.3	Fettling ML	8
CC 10 Annealing Bay	10.1	Furnace Charging	9
	10.2	Annealing	9
	10.3	Quench Hardening	9

The results of the subprocess analysis from table 5.4 are displayed in the following diagram, so that the production-technical and organisational interconnections are roughly mapped. The precise analysis of the technical-organisational and particularly the material and energy flow interlinkings are topics for the following 'Phase 3: Input-Output Analysis'.

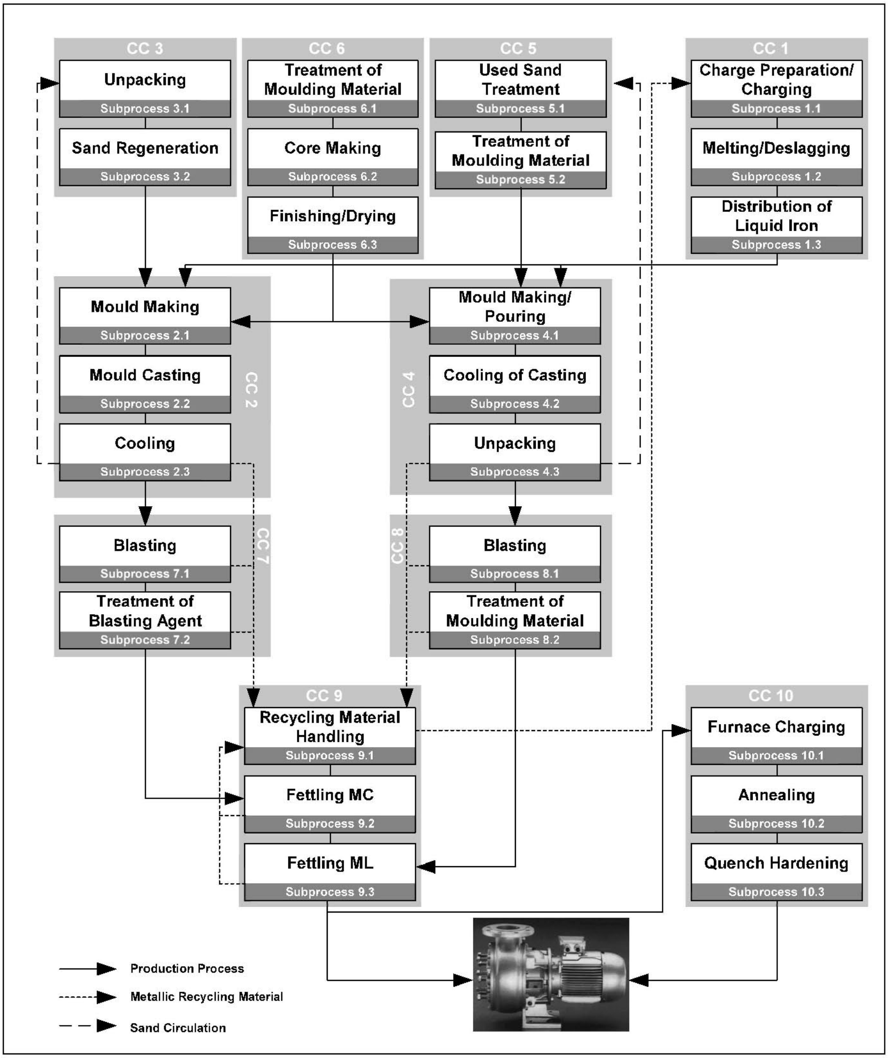

Fig. 5.7. Production-technical interconnections of direct production area[36]

[36] Source: Kuchenbuch 2004

5.3.5 Phase 3: Input-Output Analysis

In the input-output analysis, the material-energetic changes triggered by the respective decision-making tasks are registered. As already discussed, this analysis utilises the described process model and includes the determination of all material-energetic and technical-organisational transformation rules. On this basis, the actual data for 2004 was collected and the planning for 2005 was carried out for the model foundry. The results are summarised in table 5.5.

Note: Due to the number of processes, only the subprocesses of 'Cost Centre 1: Melting Process' (see Table 5.4) are examined in the following, since the significant material-energetic changes become apparent here due to the nature of the example.

Since the described transformation rules are taken as a basis for these figures, the resultant changes can be both traced backed to their causal factors and analysed in Controlling:

- The planned substitution process definitely leads to an increase in the quantity of the utilised materials (cast iron scrap and steel scrap). The reason for this is that in the 2005 plan, more material has to be used to provide the identical volume of liquid iron, since the proportion of slag in the charge preparation material increases. This is attributed to the higher degree of pollution (i.e. lower level of purity) in the cast iron scrap.
- The changes in the melting energy consumption have to be analysed against the background of the following opposite developments: since less energy is required for melting cast iron scrap, an increase in usage inevitably leads to a reduction of the melting energy. However, since more input material (skelp iron) has to be melted in order to provide the same volume of liquid iron, the energy usage is thus increased. On the whole, a constant, absolute energy consumption is therefore assumed in the example.
- Since cast iron scrap is generally more similar in substance to the required final alloy of the liquid iron, less alloying and aggregate materials are needed in terms of process materials.
- The increased slag generated by the higher degree of pollution of the cast iron scrap and the effects described above also lead to an increase of metallic soot in the furnace (metallic adherences on the furnace lining, especially in the furnace edge area). The direct effect of this is a rise in the number of furnace lining replacements, which is associated with increased consumption of refractory materials in the melting furnace and increases the corresponding waste item on the output side.

- In this context, an increase in the "Furnace Dust" output item can also be seen. Incineration of the adherences produces more dust in the waste air, which is then filtered out and has to be disposed of as waste. The higher demand on the filter performance increases the dust particle emissions, which are diffused into the environment.

Table 5.5. Input-output analysis: example[37]

	SP No.	**Input**		Actual 2004	Planned 2005
Material	1.1	Cast Iron Scrap	t	5,304.40	6,594.57
	1.1	Steel Scrap	t	6,199.47	5,000.00
	1.1	Recycling Material	t	1,943.75	1943.75
	1.1	Scrap	t	825.58	825.58
Process Materials	1.1	Carburising Agents	t	206.17	165.00
	1.1	Ferrosilicon	t	105.25	85.00
	1.2	Refractory Material	t	28.77	29.50
	1.3	Refractory Material	t	4.33	4.33
Energy	1.2	Melting Energy	kWh	7,770,959.00	7,770,959.00
	1.2	Ventilation Energy	kWh	67,600.17	67,600.17
	1.2	Gas (Ladle Furnace)	kWh	193,143.35	193,143.35
Other	1.2	Supply Air	Nm^3	46,875,000.00	46,875,000.00
	SP No.	**Output**		**Actual 2004**	**Planned 2005**
Input Material	1.3	Liquid Iron	t	14,416.57	14,416.57
	1.3	Liquid Iron Energy	kWh	5,154,207.00	5.154.207.00
Waste	1.2	Slag	t	162.92	170.50
	1.2	Refractory Material	t	10.09	10.82
	1.2	Metallic Soot in Furnace	t	18.75	19.25
	1.2	Furnace Dust	t	4.33	4.65
	1.3	Slag	t	2.88	2.93
	1.3	Refractory Material	t	1.44	1.44

[37] Source: Kuchenbuch 2004. The quantity specifications refer to an annual production output of 11,648.04 tons. Also see Footnote 116.

Table 5.5. (Cont.)

Other	1.2	Waste Heat	kWh	2,370,096.26	2,370,096.26
	1.2	Dust Emissions	kg	375.00	515.63
	1.2	Waste Air	Nm^3	46,875,000.00	46,875,000.00
	1.3	Waste Heat	kWh	507,399.26	507,399.26

5.3.6 Phase 4: Process Cost Analysis

On the basis of the quantity specifications, the respective primary process costs can be calculated for all material and energy flows that are procured by the company on the input side or which have to be disposed of at the company's expense on the output side (also refer to Table 5.6). In addition to the costs arising from the respective input and output quantities, further direct process costs and indirect process costs are shown on a subprocess level within the scope of the environmental activity-based costing. Further direct process costs include, e.g., personnel costs, maintenance expenses and calculatory or imputed costs. Moreover, not all cost centre costs can be allocated – particularly in regards to economic aspects. Thus, there is always a certain portion of costs that has to be allocated to the subprocesses as indirect process costs.[38] They then have to be consolidated into the respective main processes and from there, further allocated to the products. In the model foundry, for the purpose of reducing complexity, only 9 main processes were worked with, which were largely oriented on the cost centre structure. Table 5.4 shows what subprocesses were allocated to which main process. The following diagram illustrates the main processes of the model foundry.

[38] For more in-depth information on the topic of allocating cost centre costs to the subprocesses, see Lange and Kuchenbuch (2003a); Kuchenbuch 2004

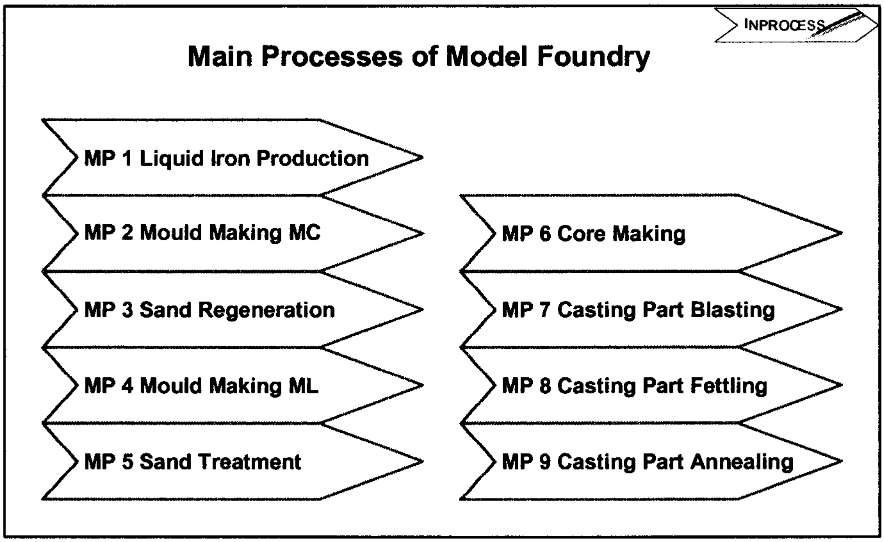

Fig. 5.8. Main processes of model foundry[39]

Figure 5.9 provides an overview of the total costs of various reference objects.[40] It also contains an aggregated form of the primary costs from table 5.6.[41]

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[39] MC = Manual Casting; ML = Moulding Line (Source: Kuchenbuch et al. 2003, p. 34)

[40] The exact way in which these costs are calculated in environmental activity-based costing is documented in detail in Lange and Kuchenbuch 2003a

[41] As already explained, Table 5.6 contains only the cost data for the spheroidal graphite cast iron, while the costs pertaining to Subprocess 1.1. and Main Process 1 are calculated as a sum total arising from spheroidal graphite and grey cast iron. A more in-depth examination would not provide provide higher informational value, but rather only have an adverse impact on the clarity. The specific alloy was only taken into account in the product analysis.

Table 5.6. Direct process costs: example[42]

	SP No.	**Input**		Actual 2004	Planned 2005
Material	1.1	Cast Iron Scrap	€	689,572.00	1,384,859.70
	1.1	Steel Scrap	€	805,931.10	1,000,000.00
	1.1	Recycling Material	€		
	1.1	Scrap	€		
Process Materials	1.1	Carburising Agents	€	98,960.64	79,200.00
	1.1	Ferrosilicon	€	73,672.90	59,500.00
	1.2	Refractory Material	€	17,262.00	17,700.00
	1.3	Refractory Material	€	2,598.00	2,598.00
Energy	1.2	Melting Energy	€	466,257.54	466,257.54
	1.2	Ventilation Energy	€	4,056.01	4,056,.01
	1.2	Gas (Ladle Furnace)	€	5,214.87	5,214.87
	SP No.	**Output**		Actual 2004	Planned 2005
Input Material	1.3	Liquid Iron	€		
	1.3	Liquid Iron Energy	€		
Waste	1.2	Slag	€	8,960.60	9,377.50
	1.2	Waste: Refractory Material	€	554.95	595.10
	1.2	Metallic Soot in Furnace	€	1,031.25	1,058.75
	1.2	Furnace Dust	€	389.25	418.50
	1.3	Slag	€	158.42	161.15
	1.3	Waste: Refractory Material	€	79.21	79.20

[42] Source: Kuchenbuch 2004. The quantity specifications refer to an annual production output of 11,648.04 tons of spheroidal graphite cast iron and therefore do not include the costs for the grey cast iron. Instead of cast iron scrap, crude iron is used for the production of grey cast iron, thus the decision-making situation applied in the example only impacts the spheroidal graphite cast iron.

Note: A change in the indirect process costs is not assumed in the example. The supposition that the calculatory and imputed costs for both periods under observation are assumed identical has to be understood from this standpoint. Changes apply to the costs for analysing the alloys as well as for the rise in the number of furnace lining replacements and the associated increase in the corresponding disposal item. These additional costs – as seen in Figure 5.9. – were accounted for in the 'Maintenance', 'Production Support' and ' Disposal Costs' cost unit groups in the 2005 planning. Furthermore, rising prices for both cast iron scrap (from 130 to 210 €/t) and steel scrap (from 130 to 200 €/t) have also been allowed for in the cost accounting.

The allocation interrelationships within the scope of the environmental activity-based costing will be illustrated by means of the reference objects presented in Figure 5.9. As previously explained, the subproccesses represent the central reference object for the integrated controlling method. This is the basis for consolidating both the material-energetic and cost-oriented data. As is shown in table 5.4, Subprocess 1.1 is allocated to Main Process (MP) 1: 'Liquid Iron Production' on a 100 percent basis. This MP is a cost collector for Subprocess (SP) 1.2 and 1.3 (each on a hundred percent basis) as well as SP 2.2 (at seventy percent). From here, the costs are further allocated depending on the extent to which a product utilises a main process. The costs of MP 1 are calculated to the respective products via the 'Required Iron Quantity' cost driver. A total of approx. 426,430.90 kg[43] of liquid iron are needed to produce the 'Type D Impeller' product, which corresponds to a proportional share of approx. 2.29%[44] of the entire liquid iron volume. With the aid of this equivalent figure, the costs of the main process are then passed on to the product. To calculate the unit cost, the specified total product cost has to be divided by 2000 (The difference in the production quantity is explained by the scrapping of 105 units).

[43] Calculation: production quantity 2,105 units; 202.58 kg/unit; total volume of liquid iron: 18,620,350 kg.

[44] For the calculation, the exact values in Figure 5.9. were calculated to all decimal places.

Costs / Reference Objects		Subprocess 1.1		Main Process 1		Typ D: Impeller	
		Actual 2004	Plan 2005	Actual 2004	Plan 2005	Actual 2004	Plan 2005
	Direct Material Costs	2,018,079.00	3,072,813.20	2,018,079.00	3,072,813.20	66,280.15	82,340.46
Direct Process Costs	Material Costs	249,405.00	215,472.00	275,102.00	241,607.00	6,300.20	5,533.12
	Energy Costs	00.00	00.00	621,495.00	621,495.00	14,233.07	14,233.07
	Personnel Costs	80,200.00	80,200.00	487,277.10	487,277.10	11,159.30	11,159.30
	Internal Services Costs	15,700.00	15,700.00	48,225.00	48,225.00	1,104.42	1,104.42
	Calc. Costs	18,000.00	18,000.00	242,787.50	242,787.50	5,560.17	5,560.17
	Maintenance Costs	21,600.00	21,600.00	277,275.00	280,515.00	6,349.97	6,424.17
	Disposal Costs	00.00	00.00	16,719.00	17,235.53	382.89	394.72
Indirect Process Costs	Material Costs	1,695.00	1,695.00	34,898.00	34,898.00	799.21	799.21
	Energy Costs	11,633.00	11,633.00	45,111.00	45,111.00	1,033.10	1,033.10
	Personnel Costs	00.00	00.00	00.00	00.00	00.00	00.00
	Internal Services Costs	12,700.00	12,700.00	24,945.00	24,945.00	571.27	571.27
	Calc. Costs	00.00	00.00	00.00	00.00	00.00	00.00
	Maintenance Costs	00.00	00.00	00.00	00.00	00.00	00.00
	Disposal Costs	880.00	880.00	5,281.00	5,809.10	120.94	133.04
	Alloc. 1: General	28,880.00	22,880.00	385,517.50	385,517.50	8,828.87	8,828.87
	Alloc. 2: Admin. + Sales	17,872.00	17,872.00	281,148.30	281,148.30	6,438.67	6,438.67
	Alloc. 3: Prod. Support	3,900.00	3,900.00	27,969.10	29,669.10	640.53	679.46
Total		2,480,544.00	3,495,345.20	4,791,883.50	5,819,053.33	129,802.79	145,233.05
				Total from the costs of subprocesses 1.1, 1.2 and 1.3 as well 70% of the costs from SP 2.2		The costs are commensurate with 2.29% of the MP 1 costs. Product quantity: 2000 pieces CD: liquid iron volume	

Fig. 5.9. Process costs of various reference objects (Source: Kuchenbuch 2004)

5.3.7 Phase 5: Performance Indicator-supported Provision of Information

As already discussed in Section 5.2.6, the main task of Phase 5 is the provision of stakeholder-oriented, performance indicator based information. As has been demonstrated, the focus lies more on the targeted supply of information pertaining to strategically relevant stakeholders with respect to a concrete decision-making situation and less on the development of a rigid performance indicator system with strictly defined contents.

But what indicators are necessary for supporting the decision-making situation described in the example and what indicators can be used to review the outcome of this decision?

First, material and energy oriented indicators should be defined for monitoring and controlling the resultant quantitative changes. Here, the focus is on those flows for which 'significant' quantitative changes have occurred (e.g. cast iron scrap, steel scrap, carburising agents, etc.) or on "sensitive" flows (e.g. dust emissions) that are very closely observed by certain stakeholders.

Examples of indicators to be developed: material usage and waste rates (kg per ton of sound castings; energy usage rates (kWh per ton of sound castings) and dust emissions (grams per standard cubic metre). In this context, particularly for materials and waste, individual performance indicators should be defined for the cast iron scrap, steel scrap, carburising agents, slag and furnace dust items.

Furthermore, in addition to a quantitative representation, there should also be a cost-related one. In the example under consideration, indicators that contain information about the resultant cost changes should especially be determined.

Examples of such indicators are: material usage and disposal cost coefficients (€ kWh per ton of sound castings).

For a thorough analysis of the effects of this decision, in addition to the indicators derived from the material and energy flow accounting as well as the environmental activity-based costing, such indicators should contain information that documents the technical-organisational changes. The most significant implications of the decision-making situation presented in the example are described in the following.

1. *Enhancement of Analytical Performance/ Quality Asssurance:* As a rule, increased use of cast iron scrap necessitates a greater number of chemical analyses of the alloy, in order to be able to guarantee the quality of the liquid iron. The less constant quality of the cast iron scrap can result in an insufficient alloy quality, which in turn can lead to increased scrap and waste in other production processes. For this reason,

the quality of the process for melting the required alloy has to be ensured through a preventive improvement in the analytical performance, or a possible error failure mode and effect analysis has to be conducted to check whether the resultant changes are tolerable[45]
Note: The following performance indicators should thus be determined: number of analyses per ton of sound castings; scrap/ waste rates (kg per ton of sound castings); number of subsequent alloyings per ton of sound castings.

2. *Filter Service Lives/ Emissions:* Since it generally has to be assumed that cast iron scrap contains more impurities than steel scrap (which also becomes manifest by the increase in the slag proportion), the melting furnace waste air is more severely polluted. As a result, more demand is placed on the filters, which reduces their service lives and may increase emissions (e.g. dust). Important indicators to be noted for these developments include: filter service lives in relation to the melting capacity per time interval; the filtered and to be disposed of dust quantity; dust emissions in the environment (g/Nm^3).

3. *Service Lives of Melting Furnaces:* Depending on the lumpiness as well as the weight of the cast iron scrap parts, a change in the wear and tear rate of the furnace lining can occur. It can generally be assumed that the increased use of cast iron scrap reduces the service life. As a result, the furnace has to be re-lined more often. However, for this process, the furnace has to be shut down, cooled off, re-lined and started up again. Since the furnace cannot be utilised for production, its efficiency decreases.
Note: In view of this, the following indicators should particularly be defined: furnace efficiency; melting capacity in tons per lining.

4. *Organisational Changes Concerning Charge Preparation:* Another issue that can arise in connection with the lumpiness of the cast iron scrap is the necessity of technical-organisational changes in the area of charge preparation (Subprocess 1.1). Depending on the condition of the cast iron scrap, large pieces may have to be crushed prior to use. Furthermore, the charge preparation process may take longer, since, due to the 'shapelessness' of the cast iron scrap, not as much material can be transported during each crane trip as is the case with, e.g., laminated sheet metal packs.
Note: Possible performance indicators here are: duration of the charge preparation process per furnace charging; space requirements of the material storage area; possible crushing time/ expense and effort in regards to the cast iron scrap.

[45] For more information about FMEA, see Ahsen and Lange 2004.

As already is made clear by this less complex example, in a first step, it is necessary to determine performance indicators pertaining to the material-energetic and cost-related effects of a decision. Moreover, while a number of production-technical parameters may be affected by this decision, they depend on a company context and thus generally cannot be examined. In this regard, an underlying data basis for a flexible performance indicator system has to be created by using the integrated controlling tools (process analysis, material and energy flow accounting, E-ABC). This in turn creates the possibility to generate situation-related information via performance indicators and provide it to the relevant stakeholders, therefore contributing to improving the quality of the decision.

It has been demonstrated that a consistent implementation of the phase model for introducing integrated controlling enables the transparent representation of a multitude of technical-organisational, material-energetic and cost-oriented effects. This representation would not be realisable to its full extent without applying the integrated controlling approach, since such data quality can only be generated via the integration in identical reference objects.

5.4 Summary

An examination of the tools discussed here (material and energy flow accounting, process-oriented costing, performance indicator systems), which can be deployed within the scope of integrated controlling, makes it evident that implementing this type of controlling concept is a complex task. However, since the utilisation of each individual tool brings considerable benefit potentials, a step-by-step introduction results in positive effects at each step and accordingly, the successive implementation of the individual concept components already promises some success. To this end, the phase model described here offers an orientation framework. Furthermore, the industry guidelines provide extensive assistance in demonstrating how integrated controlling can be implemented on the company and operational level of a foundry.[46] The establishment of the decision-making oriented performance indicator model within the scope of integrated controlling sets up the framework for conducting comprehensive causal and impact analyses on the basis of alternative system statuses.

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[46] See Lange et al. 2003, p. 37

Furthermore, it creates the option of simulating the effects of decisions or measures, thus reducing the risk of making wrong decisions.

It should also be noted here that significant expense and effort is associated with the initial establishment of the material and energy flow accounting as well as the process-oriented environmental activity-based costing and the corresponding performance indicator system. However, this expense and effort is justified by the enhanced transparency and identified saving potentials, which was particularly evidenced in the case studies analysed in the INPROCESS project.

In summary, it can therefore be stated that, in the course of the INPROCESS project, foundry-specific tools were developed and then put to the test and proven in practice. The project therefore contributed to promoting the concept of sustainable management as a state-of-the-art standard in foundries.[47]

[47] See Kuchenbuch et al. 2004, p. 28

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