Reference Data Models for the Strategic Controlling of Waste Management Firms

A New Methodology for Industry Solution Design

How can we develop industry-wide reference data models both in an inductive-empirical and in a deductive-analytical way? By means of a suitable enterprise typology and based on generic strategic objectives and performance measurement systems we show for the controlling of waste management firms how such models can be derived systematically in terms of design science research.

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1 Introduction

1.1 Problem Identification and Motivation

So far analytical information systems have only slowly found their way into waste management firms — probably because of the prevailing public law structures. Hence, in a previous study the six largest industry-specific software solutions achieved a poor result for the area of controlling functions (p&d Consulting GmbH 2004). Recent legal developments towards greater liberalization of the waste management markets, however, increase the pressure for both private and public companies to align their management with economic objectives and to improve the effectiveness and efficiency of waste management service production by industry-specific data warehouse solutions to a greater extent (Elyas and Souren 2006; Krawczik and Zisowski 2006; Krieck and Lauruschkus 2007; Nörtemann 2007). Although data warehouse standards are known for other industries (Becker and Schütte 2004; Mertens and Meier 2009; Fettke and Loos 2007, Sect. 3), there have only been sporadic and ad-hoc proposals and implementations in practice for the waste management industry (Tönsmeier GmbH&Co KG and Frankfurter Entsorgungsservice GmbH). Therefore, we set up a project in cooperation with SAP AG, which was very interested in the structured expansion of performance measurement systems despite its already existing own business solution "Waste & Recycling", and together with the waste management specialist consultancy company Carpe Dies Consulting GmbH. The aim of this project was to develop industry-specific reference data models of strategic objectives and key performance indicator systems (O&K systems).

A few years ago, Fettke and Loos noted with regard to reference modeling that only few authors (2004a, p. 11) or at least not all authors (2004b, p. 335) explain the construction approach for their model explicitly. For those cases in which the development process is clearly documented Fettke and Loos (2004a, p. 8) found that the available bulk of reference models is primarily either inductive-empirical or deductive-analytical. Despite the fact that many authors of "well-established reference models indeed refer to integrate potential reference model users and domain experts", Ahlemann and Gastl (2007, p. 78) state a lack of empirical surveys for information procurement: "The question of how this integration can be brought about, however, is typically left unanswered". These quotations also express another lack, which is a missing systematic approach of both an empirically and analytically justified industry-wide reference modeling.

1.2 Objectives, Approach, and Structure of the Paper

Consequently, our project had two objectives: (1) the derivation of generic strategic objectives and key performance indicator systems (O&K systems) for the waste management industry, including their reference data models; (2) the construction of a new methodology for the development of such industry-wide solutions that are also useful for other industries and the elimination of the aforementioned lack of a transparent systematic, both inductive and deductive approach.

The development of more appropriate reference data models faces a dilemma as there is a gap between abstraction and generality on the one hand and the adjustment in individual cases with minimal effort on the other hand. Instead of adaptive reference modeling (Becker et al. 2007), we have chosen the approach of developing different types of problems to address this dilemma. Although they each have different requirements for the corresponding models, they still have other substantial similarities (Mertens et al. 1999, pp. 73 ff.; Jost 1993, p. 33; exemplarily Packowski 1996). Therefore, we developed generic types of strategic performance measurement systems and associated data models for waste management companies. This was done both according to inductive-empirical case study methodology following Yin (2003) and in a deductive-analytical way drawing on theoretical and methodological knowledge (especially from decision theory and controlling) in accordance with the *Framework for design research* by Hevner et al. (2004, p. 80).

The structure of our paper is based on the *Design science research methodology* (DSRM) as proposed by Peffers et al. (2008). It provides both a generally accepted framework for the successful implementation of R&D projects for the design of information systems as well as a mental model that "should help researchers to present research with reference to a commonly understood framework" (p. 48). According to the first two activities of their ideal-typical DSRM process model (p. 54), the introductory Sects. 1.1 and 1.2 have identified and motivated the dual problem discussed here and have formulated the corresponding solution objectives. The following sections correspond to the four remaining activities of the DSRM process model: Sect. 2 describes our approach in the design and development of industry-wide reference data models for strategic key performance indicator systems, Sect. 3 demonstrates their functional capability for the specific case of the waste management industry, while Sects. 4 and 5 deal with the evaluation and communication. Section 3 thus also provides, partly in an exemplary way, the generic types of strategic O&K systems as the main newly created artifacts for the waste management industry (for more details and the associated multidimensional data warehouse reference data model we refer to the online Appendix of this paper; see also Elyas 2009).

2 Design of a New Development Methodology

Figure 1 provides an overview of our process model to derive industry-wide reference data model types of data warehouse systems for strategic O&K systems. The approach takes into account the standard requirements of reference models (Hars 1994, p. 15; Goeken 2004, p. 354; for critical statements on the constitutive nature of certain requirements, in particular of generality, see Delfmann 2006, p. 46 f.; Fettke and vom Brocke 2008).

2.1 Reference Data Modeling of Industry-Wide Strategic Performance Measurement Systems

2.1.1 Case Studies

Unlike other reference data model developers using internal information models as data base for generalization we start at an earlier point, i.e. with the underlying economic problem (Rosemann and Schütte 1997, p. 16). In order to investigate this problem in its essential features, we conducted case studies for this purpose. As an analytical method these belong to the qualitative empirical research approaches and are mainly used to explore how and why situations emerge (Yin 2003, p. 5). Often they result in a generalization to verifiable hypotheses or a testable theory aiming at general statements through analysis. The case study design according to Yin (2003) constitutes a suitable process model. It places great emphasis on thorough preparation, useful hypothesis formulation, sensible case selection, and a well-documented implementation, evaluation, and presentation of case study results.

In this contribution the epistemological question for the case studies is: "What determinants affect the requirement for strategic key performance indicators (KPIs) of industry members?" In this question the focus is placed on the search for typification characteristics (determinants of the need for indicators). In addition to the identification of types we gather the indicators in use and identify the demand for further indicators since – in light of the subsequent typification – specific observations could be generalizable.

2.1.2 Typification

For the formulation of useful suggestions for an industry-wide controlling via KPIs, it would be wrong to deal with future users of reference data models in a uniform way. Therefore, the model developer bears the task of supporting the adaptation process from initially universally designed prototypes to a company-specific data warehouse. Here, characteristic features of the (relevant) company (departments) serve as a basis. By means of the most important characteristics several types are distinguished already during the construction. In doing so, the configuration process is already partially run by the developer and a more adequate option is provided to the user before customization. In this way, the inductive step of case study research is followed by a deductive step of typification

Fig. 1 General procedure for constructing reference data model types

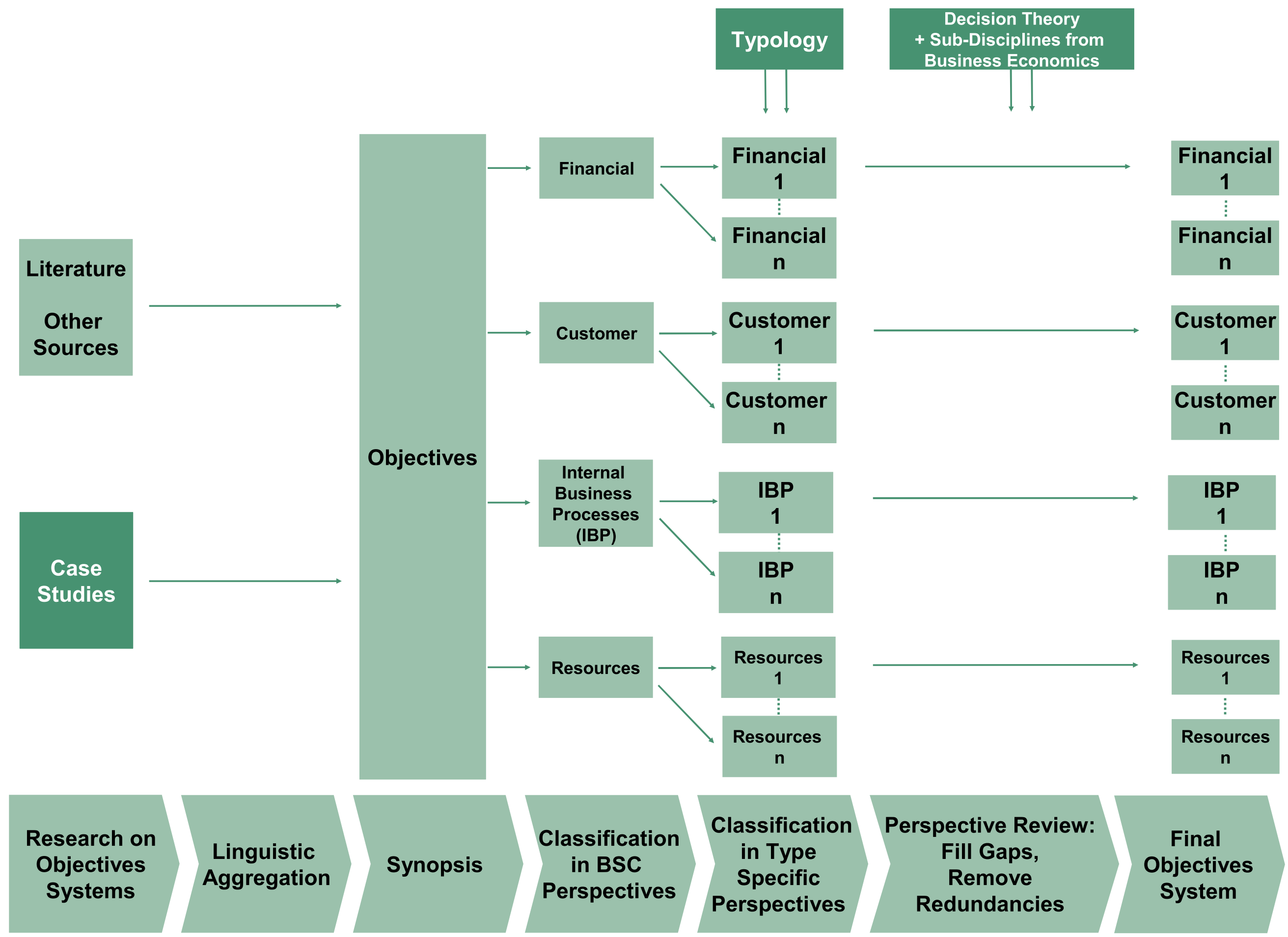

Fig. 2 Multistage Balanced Scorecard-oriented process of developing an objectives system (modified following Elyas 2009, p. 91)

in order to achieve generalizable statements from the individual case studies.

Typification can be equated with a linguistic consolidation of numerous real manifestations to the key ones. The question of which these are can only be answered with regard to the investigation's objective. The aim of the abstraction process must be to draw conclusions for any number of real cases from a few essential manifestations, the types (Dyckhoff and Finke 1992, pp. 3 ff. and 39 f.). Before developing generic O&K system prototypes, we therefore first divide the industry into groups of firms homogeneous in their need for indicators, in order to be able to provide appropriate recommendations for each group. In this article, firms are considered not only as entire companies or autonomous subsidiaries, but the term "firm" is simplistically also used for single, strategically delimitable business units or divisions within one company.

2.1.3 Type-Specific Structuring of Objectives

KPIs represent the core of the reference data models to be developed. Their full effect is only achieved if they can be selected and consolidated systematically and purposefully and if they can be represented and evaluated in analytical information systems represented as needed. Ideally, the means to achieve a performance measurement system that provides the foundation for a data warehouse should consider a theoretically sound analysis of objectives. In the prescriptive decision theory, different requirements are mentioned for objectives systems. These include the widespread elimination of means-objectives relationships within one specified decision context (fundamentality of the objectives) as well as completeness, simplicity, eliminated redundancy, measurability, and independence of preferences of the chosen objectives (Keeney 1992, pp. 82 ff.). However, a perfect objectives system, i.e. one that fully satisfies all requirements, remains mostly a utopia as these are rarely completely compatible. However, they should be taken into account to an adequate extent; even if limitations of accuracy are unavoidable for reasons of practicality. As a good compromise between accuracy and practicality we make use of the framework of the Balanced Scorecard (BSC) – which may require a modification compared to the standard set by Kaplan and Norton (1996).

Building upon the case studies and the typology we may derive type-specific objectives systems corresponding to **Fig. 2**. First, we list the objectives asserted in the case studies and add additional ones which are derived from relevant literature contributions. The strategic objectives which are determined in that way are consolidated linguistically and are assigned to BSC perspectives according to their contents. Since not all objectives are equally relevant for all business types, we

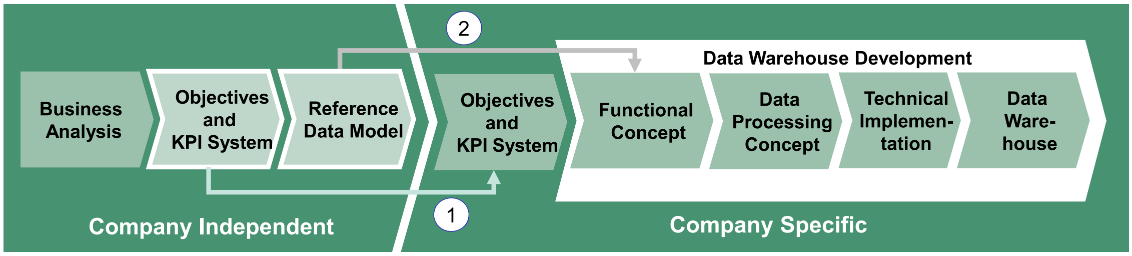

Fig. 3 Application of reference model: from objectives system to data warehouses (modified following Elyas 2009, p. 138)

carry out specific adjustments to the BSC structures and BSC contents where this is considered appropriate. In accordance with the requirements of decision theory and considering findings of related business administration sub-disciplines it appears necessary to eliminate any existing redundancies of the objectives catalog and close apparent gaps. As a result, we achieve a structured objectives system with central and generic objectives for the different types which may be applied during the implementation of concrete Balanced Scorecards.

2.1.4 Development of Type-Specific Performance Measurement Systems

Based on the conceptual preliminary design of the generic objectives systems we now specify the objectives in more detail by splitting them into sub-objectives and prototypically backing them up with KPIs for improved measurability. While the derivation of sub-objectives is still predominantly based on (decision) theory, the indicators necessarily should be tested in practice. Accordingly, we can again make use of insights from the case studies and from literature. The deductive and inductive process results in designed type-specific O&K systems constituting a useful modular specification of the basic objectives systems and thus gaining importance as a reference. However, before its practical application each O&K system needs to be adapted to the special features of each company (see Sect. 2.2) since only such a specification allows for the derivation of an analytical information system from the reference data model type.

2.1.5 Formulation of Related Data Warehouse Reference Data Model Types

The formulation of the O&K systems is followed by the development of a concept to implement a data warehouse. In order to incorporate experience with industry-typical evaluation requirements, it appears necessary to make use of both the findings of the case studies as well as functional concepts of common industry-wide business software solutions (if available) and their customer-specific adjustments during the formulation of a reference data model. The use of a similarly expressive and easily understandable modeling language makes it possible to model an industry-specific data warehouse.

Moreover, the modeled dimensions gain generalizable importance. The attributes and aggregation paths created here help to formulate the company's own functional concepts fast and in a targeted manner. In addition, it can be ensured that the O&K system is industry-wide aligned in the reference data model through the integration of the previously identified types within its own types-dimension. The entire set of the previously developed KPIs will also contribute to the reference data model with a few model-immanent adjustments. However, since the O&K system is of a modular structure, the firms should derive their own needs for indicators according to the following application principles before formulating the company's own functional concepts in order to only incorporate necessary facts (i.e. indicators of the data warehouse) in their own technical data warehouse concept. For the purposes of the reference model concept all developed structures – ranging from the individual facts up to the full data cube – are considered to be a reasonable pre-selection which have to be examined critically during the company-specific formulation of the functional concept. Thus, they must be adapted in terms of instantiation or specification (Becker et al. 2004, pp. 258 f.) or a free modification (Delfmann 2006, p. 11) and have to be supplemented where appropriate.

2.2 Recommendations for the Application of the Reference Data Model Types

As **Fig. 3** illustrates the development path from cross-company generic O&K systems to a company-specific data warehouse consists of several individual steps. The starting point is represented by the definition of the company-specific O&K system (arrow 1). Here, it is recommended but not mandatory to use the generic cross-company O&K systems as well as the included BSC methodology.

A concrete benefit of the developed process model especially results from the first stages of the specification of the company-specific strategy that allows for the appropriate use of the Balanced Scorecard in the first place. Its implementation ideally comprises the determination of strategic objectives, their connection by means of cause-effect-chains, and the selection of appropriate indicators. If these are identified, they are provided with defined objectives and strategic programs of measures which contribute to the achievement of the now specified strategy. As the generic objectives system development is anchored in decision theory and has been carried out considering specific types, the objectives can be largely adopted for the individual BSC without greater changes.

After the objectives have been determined, the sub-objectives can be defined. While companies can also follow the type-specific O&K system, the specification of the sub-objectives is more dependent on the situational emphasis of the respective firm. In particular, it is essential to examine the cause-and-effect-chains underlying the Balanced Scorecard in more detail (Ahn 2001, pp. 446 f.). The perspectives hierarchy assumed in the generic objectives system helps to faster identify dependencies between the objectives and to define their priorities in an appropriate way. As part of the subsequent KPI development companies can also follow the set of prototypical indicators; however, its suitability has to be verified in any case and possible additional requirements have to be covered by new indicators in the sense of free modification adaption form (Delfmann 2006, p. 11).

Then, the company-specific configuration of the O&K system is followed by the process of developing the data warehouse, which is not further specified in detail here. This process is again based on the reference data model (arrow 2 in **Fig. 3**) and includes several tasks, which can be divided, for example, into the three modeling steps functional concept, data processing concept, and technical implementation (Scheer 1997, pp. 14 ff.).

3 Demonstration of the Functionality for the Waste Management Industry

3.1 Case Studies

In case of the waste management industry, we used interviews to survey the strategic direction of the participating companies or their respective "firms" analyzed (see Sect. 2.1.2). We collected their main objectives, and the KPIs used for controlling (a list of the interviews and the names and classification of the participating companies can be found in Tables A-1 and A-2 of the online Appendix). Due to the small number of participating companies, which is immanent to case studies, we paid attention that the study provided a large cross-section of the relevant market participants. In the present study design, ten companies could be won as case study partners, covering the wide range of waste management firms on the market in terms of company size, legal status, and the covered disposal areas and waste types. Also in terms of their market position, the companies are diversified. In this way we ensured that also hidden influences on the KPI requirements came into view. Furthermore, we increased – as proposed by Yin (2003) – the reliability of the case study analysis by means of a multiple study design since we analyzed at least two representatives from practice for each hypothetically assumed type. The consideration of different data sources (interviews, annual reports, corporate publications, internal KPI reports, etc.) and the confirmation of research results in talks with interview partners and independent industry experts improved the validity of the survey (Elyas and Souren 2006; Souren and Elyas 2007).

3.2 Typology

The area of disposal (collection, treatment, street cleaning) and the particular type of waste (municipal solid waste vs. commercial waste) turned out to be those typification criteria which induce the strategy to the greatest extent. Their combination results in a total of six basic firm types, each with different requirements for the O&K development. The foundation of the typology by means of case studies was particularly helpful in this case as these brought about a view on the main typification criteria that differed from the prevailing opinion of experts. In the literature on "objectives systems in the waste management industry" so far the view was widespread that the corporate form (private, public, mixed forms) exerts a greater influence on the strategic orientation than the type of waste. Since the typology is meant to cover only a few, particularly meaningful and relevant sub-types, we abstained from a further typification through the addition of the corporate form or other characteristics. Thus, we only chose the six basic types and developed the reference data models for these.

Numerous discussions with users during the conduction of the case studies revealed that recent legal developments as well as competitive conditions in the waste management industry involve a convergence of the strategic orientation of private and public companies, which has also led to an adjustment of the O&K systems (this became most obvious in the discussion with Stadtreinigung Hamburg). The strategic orientation of the handling of municipal solid waste on the one hand and commercial waste on the other hand shows significant differences for both public and private waste management firms, which require a differentiated need for indicators. This statement could be confirmed by all case study companies. They often dispose of both types of waste, however, at least with regard to the KPIs used they separate the two business fields in (quasi) separate firms, some even using own subsidiaries. In order to further ensure the typology's validity, which is essential for the development of the reference data model, it was presented at professional conferences (Elyas and Souren 2006; Souren and Elyas 2007) and verified in interviews with waste management companies and consultants. Analogously to the case study survey, we thus already evaluated this modeling step during design in order to further promote the adequacy of contents of the reference models to be constructed (vom Brocke 2003, p. 148).

3.3 Type-Specific Structuring of Objectives

Based on the typification we could derive two generic strategic objectives systems – as presented in **Fig. 4** – which only differ in terms of the financial and customer perspective for municipal solid waste on the one side (left) and for commercial waste on the other side (right). The second typification criterion "disposal area" (collection, cleaning, treatment), in turn, only appeared to be relevant in the derivation of the KPIs. The survey in the case studies as well as of contributions from the relevant waste management literature resulted in a total of 30 strategic objectives. However, after eliminating redundancies and after a linguistic consolidation only 12 generic top objectives resulted, which are spread relatively evenly among the different BSC perspectives. The type-specific splitting of the BSC perspectives "finance" and "customers" in terms of the typification criteria type of "waste" is necessary due to the very different strategic orientation of municipal and commercial waste management companies. Following the citizen-value-discussion (Baum and Wagner 2000, pp. 330 ff.), we also adapted the conventional linear BSC hierarchy of objectives for the municipal solid waste management so that the financial and customer perspectives are based equally on the top level. In the internal business processes (IBP) and resource perspective, however, it is not required to differentiate objectives systems based on the particular type of waste (or the disposal area) since no strategically relevant differences were identified. Here, a specification is carried out only in the derivation of specific indicators.

3.4 Development of Type-Specific Performance Measurement Systems

For each of the type-specific BSC perspectives we developed prototypical O&K

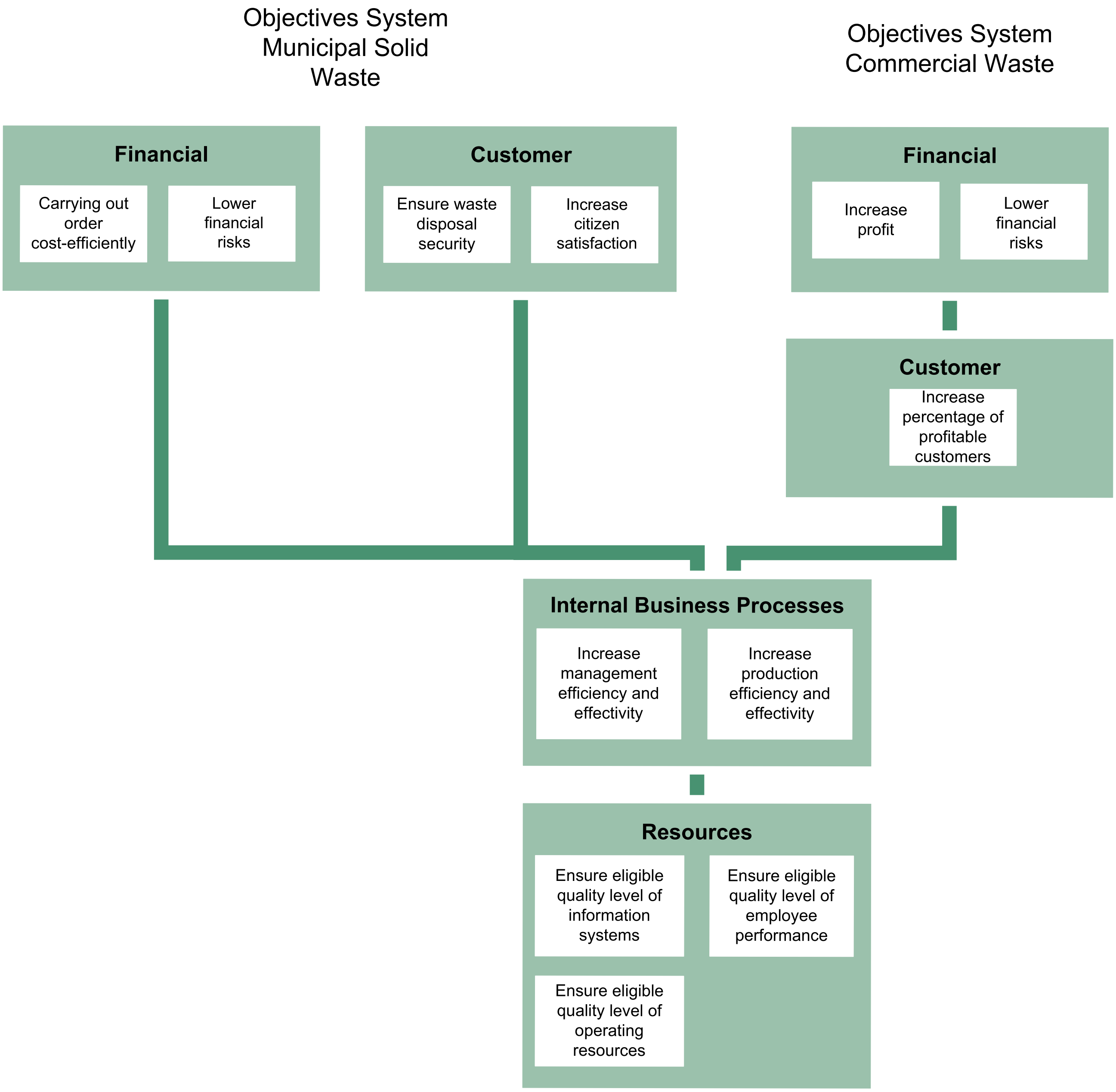

Fig. 4 Overview of generic objectives systems (according to Elyas 2009, p. 108)

systems. The 12 primary objectives become concrete in a system comprising a total of 23 sub-objectives and 117 KPIs. **Figure 5** shows, differentiated according to the three disposal areas, an example of the network of objectives, sub-objectives, and assigned KPIs for the part of the customer's perspective of the municipal solid waste management firms (the O&K systems of the five other relevant perspectives are to be found in the online Appendix). Here, mainly those indicators were used which had already been tested in practice. Most of the KPIs come from either our own case studies or are taken from literature sources that include both subject specific and non-specialist sources on the issue of controlling by means of benchmarking, performance measurement systems, or Balanced Scorecards in the waste management industry. Particularly, if the industry-specific literature contained no suitable indicators, we drew upon sources from adjacent scientific areas. Thus, for example, in the customer's perspective of commercial waste we – in accordance with the relevant marketing literature (Steffenhagen 2008, p. 66) – split up the overall objective "increase percentage of profitable customers" into the sub-objectives "increase acquisition of new customers", "increase acquisition of lost customers", and "increase service level for existing customers". Another example is the supplementation of the primary objective "ensure eligible quality level of information systems", which is rooted in the resource perspective, by the KPIs of "performance degree of technical infrastructure", "performance degree of software and system structure", and "information processing efficiency of IT personnel" (Reichmann 2001, p. 691).

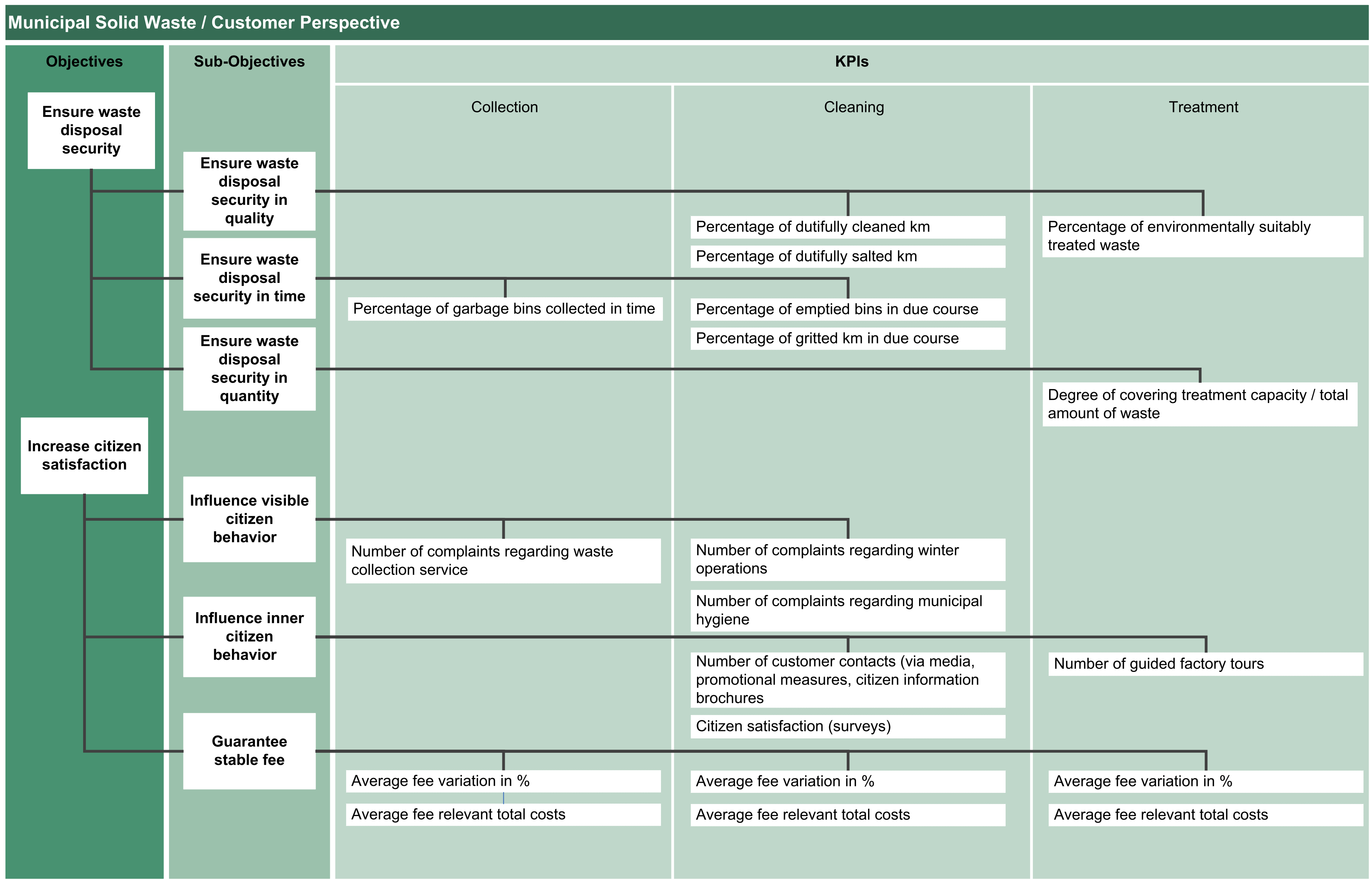

Fig. 5 Objectives, sub-objectives, and KPIs of the customer perspective "municipal solid waste" (according to Elyas 2009, p. 116)

3.5 Formulation of Related Reference Data Model Types

In addition to the self-developed O&K system, the waste management data warehouse data model by SAP AG (Industry Solution Waste & Recycling) was helpful in this development step. The structure of the reference data model for the new waste management data warehouse (Fig. A-6 in the online Appendix; Elyas 2009, pp. 169 ff.) was visualized by KOSMO (Konzept zur semantischen Modellierung multidimensionaler Datenstrukturen; engl.: approach to semantic modeling of multidimensional data structures; Elyas 2009, pp. 146 ff.; Dillschneider 2005; Totok 2000). The basic elements of the data modeling diagram are dimensions (triangles), attributes and facts (rectangles). They are connected by edges and arrows. The eight dimensions developed also contain a separate dimension for the identified types of waste management firms. The subsumed dimension attributes mark possible aggregation paths by their sequence and combination. The seven modeled groups of facts are connected with their dimension attributes by edges. This made it possible to derive seven complete data cubes for the waste management industry as a reference. The choice of indicators in the reference data model which was motivated by decision theory is expressed by the fact that the reference data model takes over the KPIs from the previously developed O&K system as the factual basis of the seven data cubes. This contributes both to its structured derivation and to its practical application.

4 Evaluation of the Data Models and the Development Methodology

4.1 Reference Data Model Types for the Waste Management Industry

For the waste management industry no comprehensive reference data models of strategic performance measurement systems exist so far. In addition, existing solutions primarily focus on firms treating waste (Stegmann 2002; Krawczik and Zisowski 2006). This paper now also considers objectives systems for companies that can be placed in the areas of waste collection and street cleaning. As an abstract description of real manifestations, the derived company-specific performance measurement systems for the first time provide a comprehensive basis for the efficient design of company-specific database models in the entire waste management industry.

The most recent interviews with experts to evaluate the models particularly showed that from the perspective of strategic orientation the six ideal types allow for a good differentiation and that the O&K systems are regarded as well structured and very comprehensive. In particular, the distinction between the ideal types according to the type of waste (municipal solid waste vs. commercial waste) is deemed to be most useful in terms of strategic considerations, especially if they, as provided in our reference data models, only concern the top two BSC perspectives (on the internal business processes and resource level a distinction is not necessary). Only one single public company suggested to additionally consider the form of ownership as an explicit typification criteria, since particular legal provisions for public firms are also relevant for the design of strategic controlling. Regarding the company-specific adjustment of the reference data models, one company expressed the desire to further improve the support of the actually required KPIs' selection by giving application recommendations. The interviews conducted for the demonstration and evaluation, however, only represent a first exploratory validation of the reference data models for the waste management industry. In terms of the sixth activity of the DSRM process model by Peffers et al. (2008), this paper thus serves to communicate the developed reference data models in view of the professional target groups in science and practice in order to expose them to criticism and to allow continuous improvements by other researchers and developers.

As mentioned earlier, demonstration and evaluation activities were integrated early into individual steps of the design and development process, keeping with Hevner et al. (2004, p. 85): "Because design is inherently an iterative and incremental activity, the evaluation phase provides essential feedback to the construction phase as to the quality of the design process and the design product under development." According to Hevner et al. (2004, p. 86), the evaluation methods used can be characterized as descriptive and only to a certain extent as analytical, experimental, and as a test; however, they can rather be characterized as empirical in the sense of user and expert judgments. They are descriptive and partly analytical insofar as they are based on the convincing application of fundamental theoretical and methodological knowledge (from decision theory, business administration, environmental economics, business and information systems engineering, etc.) in the deductive-analytical phases of the design process (Hevner et al. 2004, p. 80). In the inductive-empirical phases, industry users and industry-related experts assess the relevance and usefulness of the partly or entirely presented models based on their experience, virtually by means of thought experiments, representing an industry-wide prototype test in this respect. Moreover, the developed models are based on existing approaches from literature and practice and enhance or improve them to an industry-wide concept. A concrete implementation of the new models in waste management firms is still pending. From that point of view our evaluation accompanying the design process still needs to be supplemented by an ("observational", according to Hevner et al.) evaluation of each reference model type in practice (Becker et al. 2002, pp. 53 ff.).

4.2 Reference Data Modeling of Industry-Wide Objectives and Performance Measurement Systems

A key component of our approach is the evaluation by experts and prospective users (Frank 2007, p. 137). Here, the dichotomy of empirical and analytical reference models is repealed as theoretical knowledge, and empirical studies are integrated systematically. In doing so, the demand for the development of reference data models which are ideally characterized by both an inductive and a deductive process (Rosemann and Schütte 1997, p. 16) is met. For the proposed development methodology we used both scientific analyses (case study research, typification), which can be generally made fruitful for reference modeling, and theoretical knowledge of business administration sub-disciplines, such as decision theory and control, which are generally relevant to the development of reference data models for industry-wide strategic performance measurement systems. The practicality of the approach and the validation of the developed model types in the case of the specifically analyzed waste management industry are based both on close cooperation with companies concerned and the critical evaluation by experts during the entire process.

An essential characteristic of the presented approach is seen in the type-dependent reference modeling, as it was conceptually considered and also partly implemented in various literature contributions (see the sources mentioned in the introduction). The special feature of our method is the fact that practitioners are already consistently integrated into the typification process and thus the risk of creating irrelevant types is reduced. In addition, the typology is deliberately restricted to a limited number of ideal types which are based on few key typification criteria. The ideal types help the user to pre-select, without creating the impression that there is no further need for a comprehensive company-specific adjustment.

5 Communication for Further Evaluation in Science and Practice

The starting point of our project was the dissatisfaction in the waste management industry and of respective consulting and software companies as brought to us being waste management and controlling experts. They complained about the lack of balanced (strategic) performance measurement systems and corresponding reference data models in science and practice. Hence, the first objective was to derive generic strategic waste management performance measurement systems and their reference data models. As a second goal, the construction of a new industry-independent development methodology for such industry-wide reference models resulted.

The R&D process, which was initiated regarding the first objective, included all six DSRM activities as proposed by Peffers et al. (2008), even though to a greatly varying extent, and went through this process several times. We also early integrated demonstration and evaluation activities into individual steps of the design and development process (according to Fettke and Loos 2005, p. 22):

1. The identified and above mentioned problem of lacking controlling support by appropriate, in particular strategic information systems in the waste management industry motivated the R&D project.
2. The project's defined objective first was the development of appropriate reference data models of strategic performance measurement systems for the waste management industry. The target group of these models is primarily made up of software companies which offer a data warehouse solution for waste management firms as well as consulting companies supporting waste management firms in the implementation of such solutions.
3. For the proper construction and development of these models we developed the novel approach as presented in Sect. 2 (see second objective), which again requires six comprehensive sub-activities to be carried out (**Fig. 1**). In particular the first three of these steps already include demonstration and evaluation activities, through which the models could not only be validated but also further developed and improved in an iterative way.
4. The functionality and usefulness of the six developed company-specific reference models and their components as derived in Sect. 3 were demonstrated by presentations of the models at conferences on the one hand and by the fact that the models largely build upon, enhance, and systematically improve existing approaches from literature and practice on the other hand.
5. In a series of interviews and discussions with experts from the firms, consultants, and software houses concerned, we evaluated the relevance and usefulness of the developed (partial) solutions already during the design and development process and, where necessary, improved them by means of an iteration loop.
6. In addition to the previous more practice-oriented publications (Elyas and Souren 2006; Souren and Elyas 2007) and the thesis of Elyas (2009), this paper (inter alia) supports the communication in the scientific community and thus enables (as an additional, seventh activity) the evaluation and improvement by independent researchers.

Abstract

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Reference Data Models for the Strategic Controlling of Waste Management Firms

A New Methodology for Industry Solution Design

The paper depicts the development of reference data models for strategic key performance indicator systems specific to waste management firms providing a new comprehensive typology of generic models for data warehouse solutions. Additionally, a development methodology for industry solutions is applied, which, given the empirically founded typification process and the theoretically derived performance measurement systems, is characterized by a high degree of structure and transparency. The new approach thus systematically integrates both inductive-empirical and deductive-analytical elements.

Keywords: Reference data model, Design science research methodology, Strategic controlling, Case study, Typology, Balanced scorecard, Key performance indicators, Waste management

In regard to the second objective not all activities of the DSRM process have been realized yet. This paper demonstrates the effectiveness of our novel approach to modeling reference data models for industry-wide strategic O&K systems for the case of the waste management industry. We are aware of the fact that the evaluation of the methodology in relation to other industries is missing. However, this is outside our possibilities.

In this context, Frank (2007, p. 137) sums up: "For a number of reasons, the evaluation of reference models is a challenging, yet important task." In general, Winter (2008, p. 470) states in his guest editorial on *Design Science Research in Europe*: "A final example for the need of rigour improvement in IS design science research is the lack of commonly accepted, specific evaluation guidelines for the different artefact types." Some help, however, is provided by the framework proposed by Frank (2007) and the generic process for the evaluation of reference models. He remarks (p. 136): "Although the framework includes four perspectives, it might not be appropriate to use all of them in every project." And he concludes (p. 137): "Therefore, ... a pragmatic solution is required." In this sense, we have considered at least the following important aspects of his four perspectives of evaluation by means of the project-supporting discussion and successive further development of reference data model types based on decision theory and case studies with potential users of different waste management firm types:

- The adaptability, effectiveness, and efficiency of the economic perspective,
- the understandability, appropriateness, and acceptance of the deployment perspective,
- the definition of the scope and purpose of application of the engineering perspective,
- and various aspects of the epistemological perspective, such as precision, abstraction, and originality.

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Reference Data Models for the Strategic Controlling of Waste Management Firms

A New Methodology for Industry Solution Design

Harald Dyckhoff, Rainer Souren, Abdulla Elyas

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Appendix (available online via http://springerlink.com)

Table A-1 Interviews in the development process of the reference data models

Contents (acc. to DSRM process)	Interview partners	Date
Problem identification and determination of objectives	• SAP AG (Product Manager IT-Solution Waste Management and Recycling, Marketing Manager, Business Intelligence) • Carpe Dies Consulting GmbH (Consultants for Controlling and IT) • Waste management companies, software developers, industry consultants (from the BI group of SAP AG)	February 2004, August 2004, April 2005 January 2005, April 2005 June 2005
Case study interview as a first development step	• AWA Entsorgungs GmbH Aachen • AWISTA GmbH Düsseldorf • AVA Abfallverwertung Augsburg GmbH • Frankfurter Entsorgungs- und Service GmbH • MVA Bonn GmbH • AWS Abfallwirtschaft Stuttgart • Stadtreinigung Hamburg A.ö.R. • Landbell AG Mainz • Tönsmeier Dienstleistungs GmbH&Co KG Porta Westfalica • Sita Deutschland GmbH Köln	May 2005 June 2005 June 2005 June 2005 June 2005 June 2005 June 2005 July 2005 July 2005 August 2005
Evaluation of case study results in interviews with experts accompanying the development phase	• Waste management companies, software developers, industry consultants (from the BI group of SAP AG) • Waste management companies, software developers, industry consultants (at professional conferences of the association of municipal waste management and city cleaning (ger.: Verband Kommunale Abfallwirtschaft und Stadtreinigung, VKS)	February 2006 September 2006, November 2007
Demonstration and evaluation of the reference data models during interviews with experts, case study companies, and further waste management firms	• Carpe Dies Consulting GmbH (Consultants for Controlling and IT) • MVA Bonn GmbH • HML GmbH Kempten / Schönmakers Umweltdienste GmbH Goch • Aachener Stadtbetrieb • Frankfurter Entsorgungs- und Service GmbH	December 2009 December 2009 December 2009 January 2010 January 2010

Table A-2 Case study companies

Company	Type of waste		Area of disposal			Type of ownership
	MWM	CWM	Treatment	Collection	Cleaning	
AVA Abfallverwertung Augsburg GmbH	X	X	X			PPP
AWA Entsorgungs GmbH Aachen	X	X	X			public
AWS Abfallwirtschaft Stuttgart	X	(X)		X	X	public
AWISTA GmbH Düsseldorf	X	X-T	X-T	X	X	PPP
Frankfurter Entsorgungs- und Service GmbH	X	X-T	X-T	X	X-T	PPP
MVA Bonn	X	X	X			public
Sita GmbH Köln	X-T	X-T	X	X		private
Stadtreinigung Hamburg A.ö.R.	X	X	X-T	X-T	X-T	public
Tönsmeier Dienstleistungs GmbH&Co KG Paderborn	X	X	X	X		private
Landbell AG Mainz	X		System service provider dual system for packaging waste			private

<u>Legend:</u>

MWM: Municipal solid waste management   CWM: Commercial waste management

X: Type of disposal offered separately by the company

(X): Type of disposal offered integratively by the company

-T: Type of disposal predominantly managed by subsidiaries or participations

PPP: Public Private Partnership

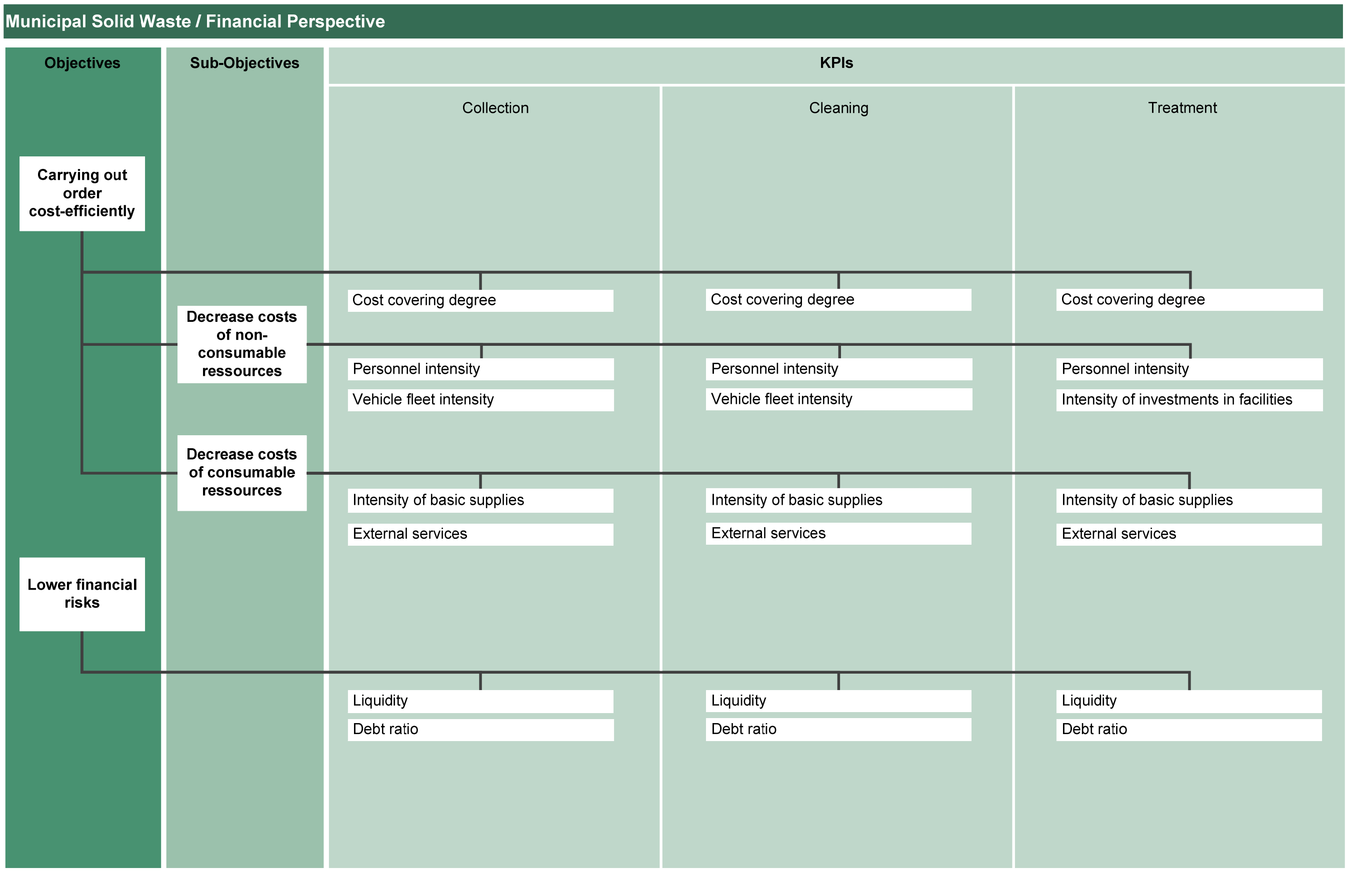

Fig. A-1 Objectives, sub-objectives, and KPIs of the financial perspective “municipal solid waste” (according to Elyas 2009, p. 111)

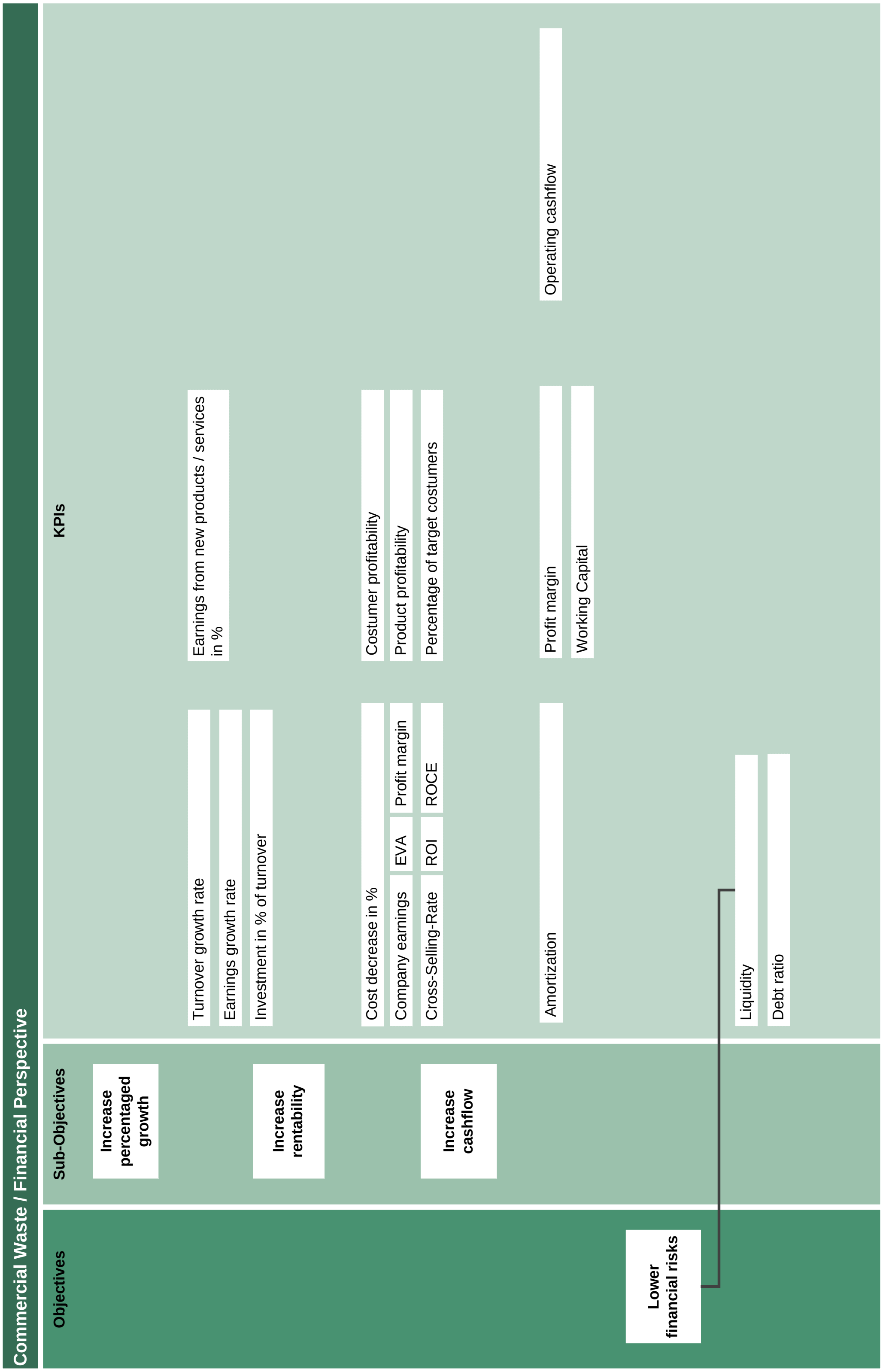

Fig. A-2 Objectives, sub-objectives, and KPIs of the financial perspective “commercial waste” (according to Elyas 2009, p. 122)

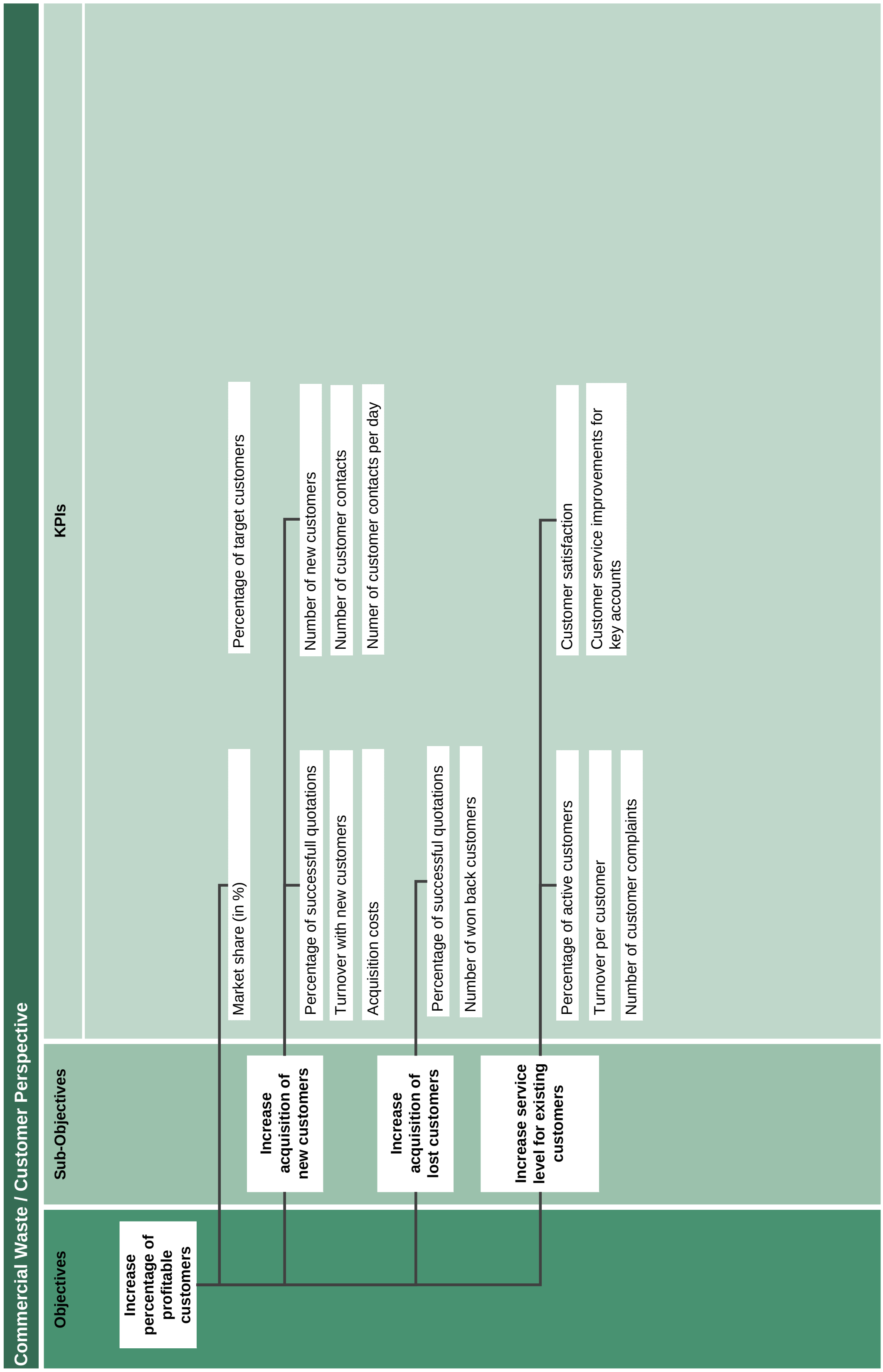

Fig. A-3 Objectives, sub-objectives, and KPIs of the customer perspective “commercial waste” (according to Elyas 2009, p. 124)

Internal Business Processes Perspective

Objectives	Sub-Objectives	KPIs: Collection	KPIs: Cleaning	KPIs: Treatment
Increase management efficiency and effectivity		Number of scheduled orders	Number of scheduled orders	Number of scheduled orders
		Percentage of disposition time	Percentage of disposion time	Percentage of disposition time
		Personnel costs at administration per collected tonnage	Personnel costs in administration per cleaned km	Personnel costs in administration per treated tonnage
Increase production efficiency and effectivity	**Output-related variables**	- Collected tonnage - Collected bin volume - Number of tours (municipal solid waste) - Number of disposal orders (commercial waste) - Number of collections - Number of collection days - Degree of being on call (commercial waste)	- Number of garbage bins collected - Amount of grit - Amount of sweeping - Cleaned stretch of road in km - Cleaning quality - Response time after hotline call (streetcleaning) - Degree of being on call	- Throughput of treated waste amount - Output for sale - Output for disposal - Emission quality
	Process-related variables	- Change-over times / duration of break / performance time per operation - Collection / treatment / unloading time per operation - Number of collections per time unit ---------- - Number of under-/overstaffed tours - Number of collections per waste collector (or team) - Number of collections per driven km - On average covered distance ---------- - Deviation from executing time (commercial waste) ---------- - Degree of vehicle utilization - Degree of vehicle availabilty	- Change-over time / duration of break / performance time per operation - Collection / treatment / unloading time per operation - Number of garbage bin collections per time unit - Cleaned stretch of road in km per time unit ---------- - Sweeping amount per cleaned km per time unit - Sweeping amount per employee - Number of garbage bin collections per employee ---------- - Deviation from executing time (commercial waste) ---------- - Degree of vehicle utilization - Degree of vehicle availabilty	- Processing time per delivering vehicle - Tipping per time unit - Throughput time per garbage bin - Downtime due to revision - Downtime due to repair ---------- - Throughput amount per waste type ---------- - Process quality (fire and accident prevention etc.) ---------- - Capacity utilization per plant component
	Input-related variables (costs)	- Total costs (per collected tonnage) - Personnel costs - Maintenance costs - Fuel costs - Costs due to vehicle shortfall (calculatory loss) - Financing costs - Depreciation costs	- Total costs (per collected tonnage) - Personnel costs - Maintenance costs - Fuel costs - Costs due to vehicle shortfall (calculatory loss) - Financing costs - Depreciation costs	- Total costs (per collected garbage bin) - Personnel costs - Maintenance costs - Fuel costs - Costs due to vehicle shortfall (calculatory loss) - Financing costs - Depreciation costs

Fig. A-4 Objectives, sub-objectives, and KPIs of the internal business processes perspective (according to Elyas 2009, p. 128)

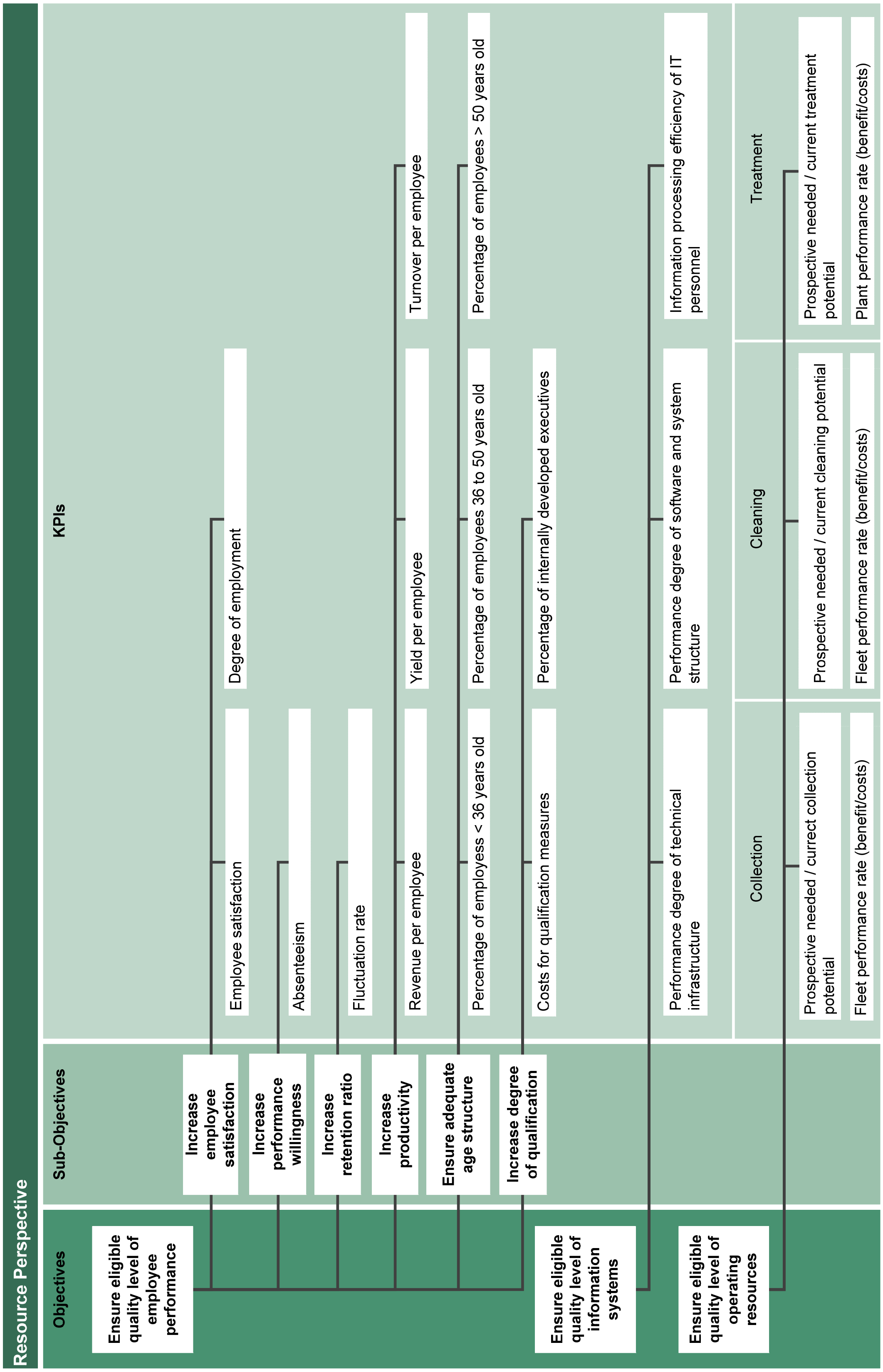

Fig. A-5 Objectives, sub-objectives, and KPIs of the resource perspective (according to Elyas 2009, p. 132)

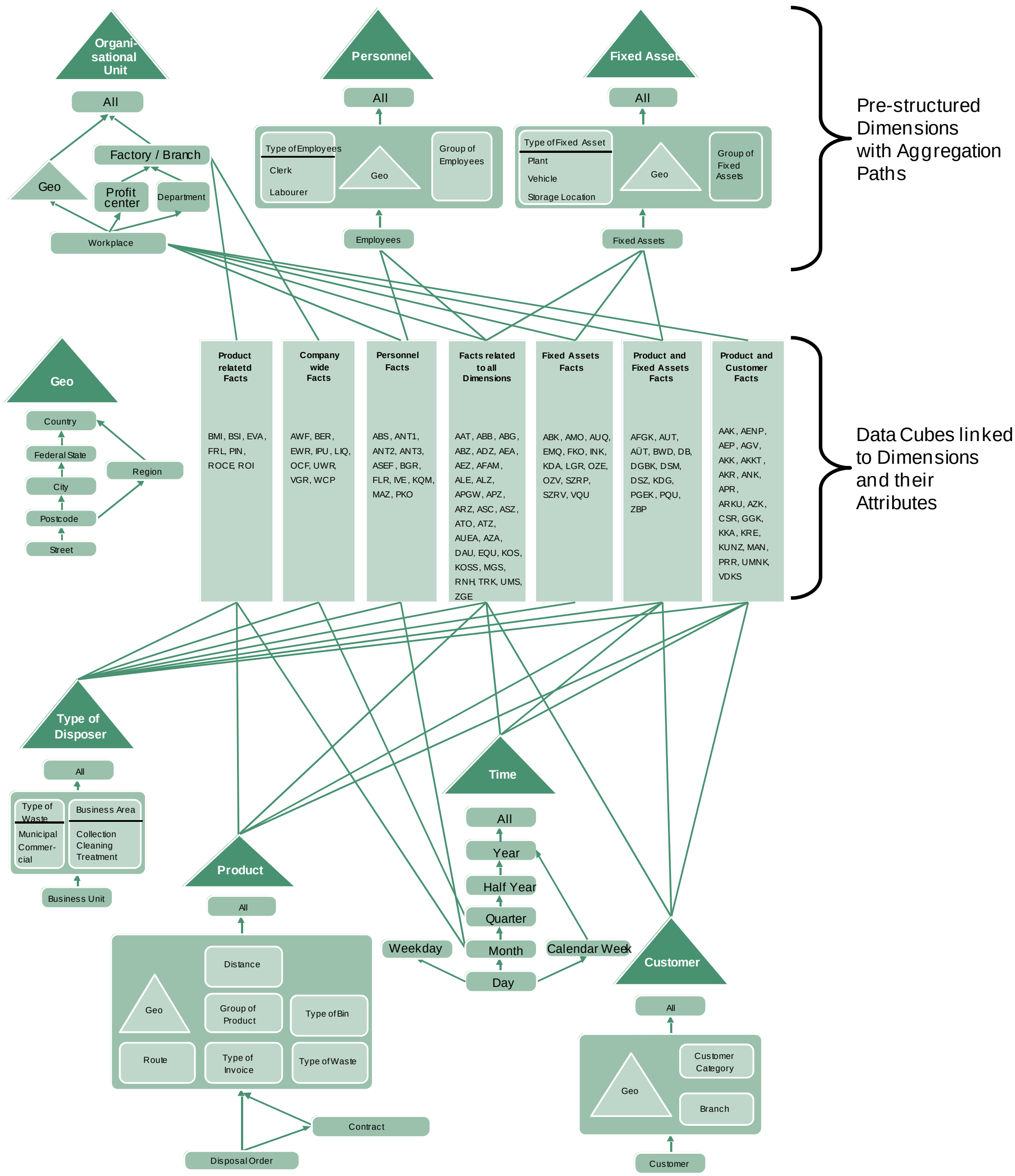

Fig. A-6 Multidimensional reference data model for waste and recycling industry data warehouses (modified following Elyas 2009, p. 188)

Legend for Fig. A-6

Abbreviation	Fact
AAK	Percentage of active customers
AAT	Number of garbage collection days
ABB	Processed bin volume
ABG	Weight of waste
ABK	Depreciation costs
ABS	Absenteeism
ABZ	Processing time
ADZ	Percentage of disposition time
AEA	Number of disposal orders
AENP	Percentage of revenue from new products/services
AEP	Percentage of successful quotations
AEZ	Percentage of unloading time
AFAM	Percentage of garbage bins collected in time
AFGK	Percentage of km cleaned/salted on time
AGV	Average fee variation in percentage
AKK	Acquisition costs
AKKT	Number of customer contacts
AKR	Number of customer complaints
ALE	Number of collections
ALZ	Garbage collection time in percentage
AMO	Amortization
ANK	Number of new customers
ANT1	Percentage of employees < 36-years old
ANT2	Percentage of employees 36 to 50 years old
ANT3	Percentage of employees > 50-years old
APGW	Percentage of dutifully cleaned/salted km
APR	Number of PR measures
APZ	Percentage of pause time
ARKU	Number of won back customers
ARZ	Percentage of set-up time
ASC	Number of tipping
ASEF	Percentage of internally developed executives
ASZ	Percentage of collection time
ATO	Number of tours
ATZ	Percentage of transportation time
AUEA	Percentage of environmentally suitably disposed waste quantity
AUQ	Capacity utilization rate
AUT	Number of understaffed tours
AÜT	Number of overstaffed tours
AWF	Number of factory visits
AZA	Deviation from executing time
AZK	Percentage of target customers
BER	Operating profit
BGR	Level of employment
BMI	Intensity of fixed assets
BSI	Intensity of basic supplies
BWD	On call level of winter road clearance, street cleaning
CSR	Cross-selling-rate
DAU	Number of scheduled orders
DB	Gross margin
DGBK	Degree of covering of treatment capacity / total amount of waste
DSM	Amount of throughput
DSZ	Processing time
EMQ	Emissions quality
EQU	Disposal quality
EVA	Economic value added
EWR	Earnings growth rate
FKO	Financing costs
FLR	Fluctuation rate
FRL	External services
GGK	Average fee relevant total costs
INK	Maintenance costs
IPU	Investment in % of turnover
IVE	Information processing efficiency of IT personnel
KDA	Costs due to downtimes (calculatory loss)
KDG	Cost covering degree (i.e. ratio between costs and proceeds)
KKA	Customer contacts / offers * 100
KOS	Costs
KOSS	Cost decrease in %
KQM	Costs for qualification measures
KRE	Customer profitability
KUNZ	Customer satisfaction
LGR	Performance rate
LIQ	Liquidity
MAN	Market share
MAZ	Employee satisfaction
MGS	Amount of grit
OCF	Operating cash flow
OZE	Output for disposal
OZV	Output for sale
PGEK	Primary commodity deployment costs
PIN	Personnel intensity
PQU	Process quality
PRR	Product profitability
RNH	Response time after hotline call
ROCE	Return on capital employed
ROI	Return on investment
SZRP	Downtime due to repair
SZRV	Downtime due to revision
TRK	Fuel costs
UMNK	Turnover with new customers
UMS	Turnover
UWR	Turnover growth rate
VDKS	Customer service improvement for key accounts
VGR	Debt ratio
VQU	Availability rate
WCP	Working capital
ZBP	Prospectively needed / current disposal potential
ZGE	Covered distance