Resource Management for the Construction Industry

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Summary
The management of resources is an essential task in each construction company. Today, ERP systems and e-Business systems are available to assist construction companies to efficiently organise the allocation of their personnel and equipment within the company, but they cannot provide the company with the idle resources for every single task that has to be performed during a construction project. Therefore, companies should have an alternative solution to better exploit expensive resources and compensate their fixed costs, but also have them available at the right time for their own business activities.

This paper outlines the approach taken by the EU funded project "e-Sharing" (IST-2001-33325) to support resource management between construction companies. It will describe requirements for the management of construction resources, its core features, and the integration approach. Therefore, we will outline the approach of an integrated resource type model supporting the management and classification of construction equipment, construction tasks and qualification profiles. The development is based on a cross-domain analysis and evaluation of existing models.

Furthermore, a mapping and merging strategy, enabling and supporting the integrated usage of the existing, standardised, singular models and content descriptions will be explained. The objective of the integrated resource type model is to provide an appropriate method for managing different resource categories and types and generate a harmonised set of descriptive attributes and appropriate relationships.

1 Introduction
While performing a construction project companies have to determine whether to work with their own equipment and personnel or to rent these resources. Therefore, the main objective of the e-Sharing project is to design, develop and evaluate a service provided by a third party for the efficient management and allocation of resources between different companies. Resources shared through e-Sharing can be of varying types like equipment, human resources, buildings, and warehouse space, described by a resource type model that was designed in the e-Sharing framework. Therefore, the user has to describe the tasks they need to accomplish and e-Sharing will propose the required resources for its conduction. The suggested resources are selected from a shared resource pool that includes all available resources of the system.

A pre-requisite for the e-Sharing approach is the availability of an integrated resource description model. To describe a specific set of resources, an extensive number of parameters have to be taken into account that can be individually selected and weighted. Within the next sections the development approach of the integrated resource type model supporting the integrated management of AEC-specific equipments, qualification profiles and services is described. It should be noticed, that services can be interpreted as combination of necessary equipment and required qualification profiles to use a specific type of equipment

2 Analysis and Evaluation of Existing Schemata and Content Descriptions

The basis for the development of the integrated resource model in the e-Sharing project was an analysis of existing standards and catalogues describing construction equipments, construction tasks, and qualification profiles to select the most detailed and general content descriptions and the appropriate models. The analysis was divided into two sub-tasks: Firstly, content information for equipments and tasks as well as qualification profiles in the construction sector was analysed. In a second step the content specification was compared to existing standardized schemata in order to define the appropriate schema to manage and maintain resource information.

The evaluation process was conducted in close cooperation with industry partners and further potential end-users of the e-Sharing system to continuously consider their requirements and experiences. In the following sections the selected content information and the corresponding models are described.

2.1 Existing Content Descriptions for Construction Equipment

One of the resource types that will be managed in the e-Sharing system are construction equipments. The BGL 2001 ("BauGeräteListe" - German National List of Construction Equipment, see Baugeräteliste 2001) specifies technical and relevant financial information about equipment types in the construction sector. The BGL 2001 is used for the estimation of costs as well as technical performances of construction equipment. The BGL 2001 is divided into 24 main-equipment-groups, which are identified by a certain id number. The main-equipment-groups are further subdivided into: equipment-group, equipment-sub-group, and device-type.

Each equipment type is specified by characteristic technical properties like height, load moment or velocity. In the e-Sharing system these technical attributes will be used by the lessor as classification template. Templates will be further specified (or instantiated) into specific equipment description sets.

Based on the BGL 2001 the so called EUROLISTE has been developed in cooperation of French and German authorities. The aim of the EUROLISTE is to harmonize standards for construction equipment in Europe. It was first published in 1998 and will be implemented European wide (starting in Belgium, Austria but also in other EU-countries, and even overseas).

Finally, one can conclude, that the EUROLISTE / BGL 2001 is the most complete and most detailed content description of equipment types in the construction sector. Therefore, we have chosen the EUROLISTE / BGL 2001 as content description.

2.2 Existing Content Descriptions for Construction Tasks

In the e-Sharing system lessees shall be able to specify the task they intend to perform and in turn the system will propose the appropriate equipment and – if necessary – required qualification profiles to operate a certain type of equipment. Therefore, descriptions of possible construction tasks were analysed.

For construction projects in Germany the STLB ("StandardLeistungsBuch" – Book of Standardised Construction Service Description, see Standardleitungsbücher until 2004) categorises construction tasks in a hierarchical order identified by a certain id number. Furthermore, each task can be specified by certain properties which will describe the amount of work that has to be performed. Currently, the STLB is the most complete and most detailed content description of task types in the European construction sector. Therefore, the STLB was chosen in e-Sharing as content description for construction tasks.

2.3 Schemata for Modelling of Equipment and Tasks

In order to determine the appropriate model that describe equipment types and task types for the e-Sharing system two different criteria have been identified: Firstly, information of equipments and tasks has to be structured hierarchically while attaching certain properties to them. Thus, inheritance of properties must be supported. Secondly, in order to find the appropriate equipment for a certain task equipment types and task types must be comparable. Consequently, the two models shall be compatible. These requirements are sufficiently covered by the bc-XML (developed within the '*eConstruct*' project (www.econstruct.org) specification, which can be used for both, the equipment type description and the task type description. Figure 1 illustrates how the bc-XML architecture is adapted for the e-Sharing requirements.

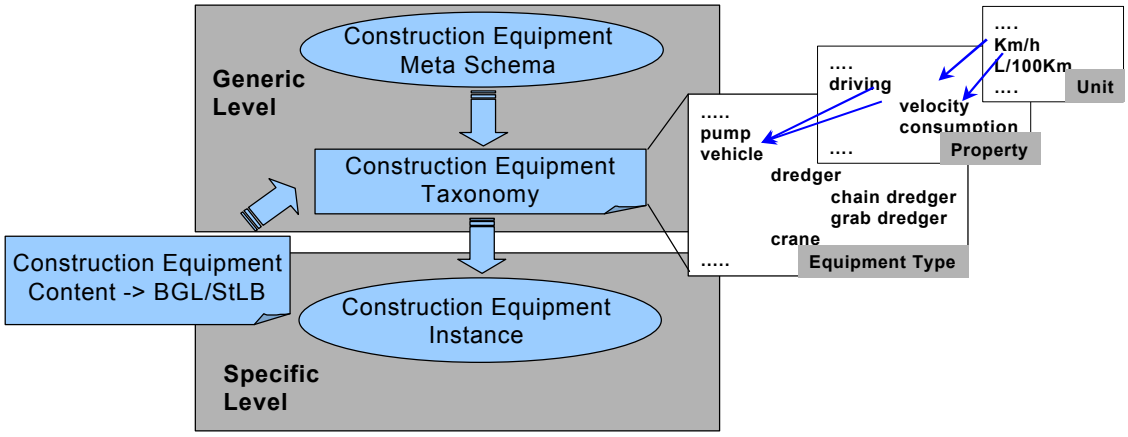
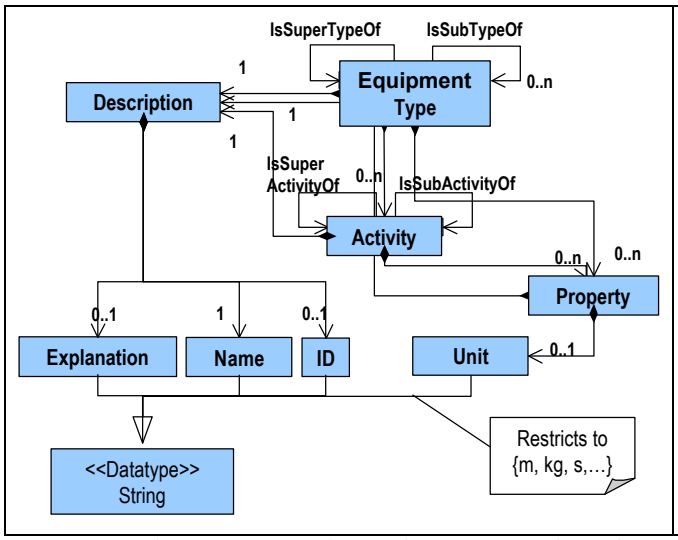


Figure 1: Architecture of equipment description adapted from bc-XML

In e-Sharing a bc-XML compatible Meta Schema is specified on the Generic Level. Taxonomies can be developed using the BGL 2001 (equipment) and the STLB (task) derived from the Meta Schema. On the Specific Level the Equipment Types and Task Types will be instantiated by specifying the values of the required technical properties. Consequentially, an instance of an equipment type can be described as follows (using XML):

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<EquipmentType>
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             </Loadmoment >
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             <Speed unit="km/h">
              <value>50</value>
             </Speed>
          </MaxVelocityProperty>
    </SlewingTowerCraneTrolleyJibType>
</EquipmentType>
```

Figure 2: Construction Equipment Meta Schema / Construction Equipment Instance (XML)

2.4 Existing Content Descriptions for Qualification Profiles in AEC

Under the guidance of the British Department of Education and Employment (DfEE) the Construction Industry Standing Conference (CISC) (see www.cisc.org.uk) developed a framework for National Vocational Qualifications (NVQ) (s. http://www.uce.ac.uk), and Scottish Vocational Qualifications (SVQ). The first version was delivered in 1994.

Within the Europroject for "Use of Standards of Competence in CPD for Construction Industry Practitioners" (s. http://www.cicsc.org.uk/euscccip.htm) a broad validation took place in the U.K., Portugal, Finland, Ireland, France, Germany, Hungary, Romania, etc. Within e-Sharing the descriptions of 'level 4' and 'level 5' qualifications in the construction sector will be used.

Under the guidance of the German Assembly of the "Chambers of Handicrafts" app. 50 job descriptions are maintained as standardised qualification profiles (comparable to 'level 1' to 'level 3' of the NVQ's). The job descriptions are continuously up-dated and synchronised between French, Austrian and German authorities. The CISC-approach and the job descriptions complement each other. This holistic approach ensures the usability of our approach to different organization types within the construction sector.

2.5 HR-XML – A Schema for Qualification Profile Descriptions

Within the e-Sharing project human resources (HR) are characterised through knowledge and skills of a person (like a certificate for crane operation or a welding certificates). Therefore, the schema describing the qualification profiles has to fulfil two requirements: Firstly, it should be a neutral standard in order to allow integration of information from external systems, and secondly, the content for skills and knowledge (as described above) has to be represented in the schema.

The HR-XML (www.hr-xml.org) specification supports these requirements to the best. The HR-XML consortium is a non-profit group that is developing standard XML-vocabularies for the human resource management profession. HR-XML is one of the largest and best-supported XML standards supporting specific business requirements used by more than 120 member organisations (such as SAP, Schlumberger, Bundesanstalt für Arbeit (German Office for Employment), IBM, Microsoft). HR-XML includes test results, reports, performance appraisals, evaluations, certificates, licenses, or a record of direct observation, such as a report given by a former supervisor or other employment reference. Furthermore, it allows to capture information describing the relative importance of one specific Competency or the Sufficiency required.

Within the HR-XML specification the competencies are described as: *'A specific, identifiable, definable, and measurable knowledge, skill, ability and/or other deployment-related characteristic (e.g. attitude, behaviour, physical ability) which a human resource may possess and which is necessary for, or material to, the performance of an activity within a specific business context.'*

Being a neutral and well-supported standard for qualification profiles, HR-XML provides an excellent interface to integrate external information into the e-Sharing system. Tests have shown that the described content information for construction and ICT qualification profiles can be represented with the Competency component of the HR-XML specification.

2.6 Evaluation

By applying two well established XML-based schema definitions – bc-XML (construction equipment and tasks) and HR-XML (qualification profiles) -a holistic, integrated modelling approach becomes possible. In addition selecting well proven content descriptions from the AEC-sector user acceptance on a broad basis is ensured within the e-Sharing integrated resource modelling approach.

Table 1: Overview of analysed XML-specifications and analysed content sources

Category	Models & Schemas	Comment	Content Descriptions	Comment
Equipment	**bcXML**	**Result of FP5 Project**	**BGL-2001**	**German Industry Standard Standardization on EU level in progress**
Task	**bcXML**	**Result of FP5 Project**	**STLB**	**German Standard**
	Ifc 2.x-Task	SubSet of Ifc 2.x (needs to be extended)		
Qualification Profiles	**HR-XML**	**Cross-sectorial Industry standard**	**CISC** **AEC Qualification Profiles**	**Consolidated results of multiple EU projects German Standard co-ordinated with Austria and France**
	Ifc 2.x-Organization	SubSet of Ifc 2.x (needs to be extended)		
	Wf-XML	WfMC-based standard (does not address specific needs like qualification / skill level etc.)		
other models & schemas analysed	ebXML	OASIS initiative (non organizational / HR specific part available)		
	aecXML	AEC Industry standard (needs to be heavily extended) (development driven by US-based company)		

3 Resource Type Model Integration

The objective of the integrated resource type model is to provide an appropriate method for managing different resource categories and types and generate a harmonised set of descriptive attributes and appropriate relationships. Therefore, within the e-Sharing project mapping and merging strategies, enabling and supporting the integrated usage of the existing, standardised, singular models and content descriptions are developed. The strategy will contribute to the development of a homogeneous description of the integrated e-Sharing resource model.

The integrated e-Sharing model will support leasing-concepts on a cross-sectorial, international way (and not only within one specific industry sector) and finally lead to improved business opportunities. In this way SMEs can exchange their services more efficiently. ICT-services will become easier available to the construction sector. Figure 3 illustrates the integration process of the domain-specific schemata and content descriptions described in chapter 2.

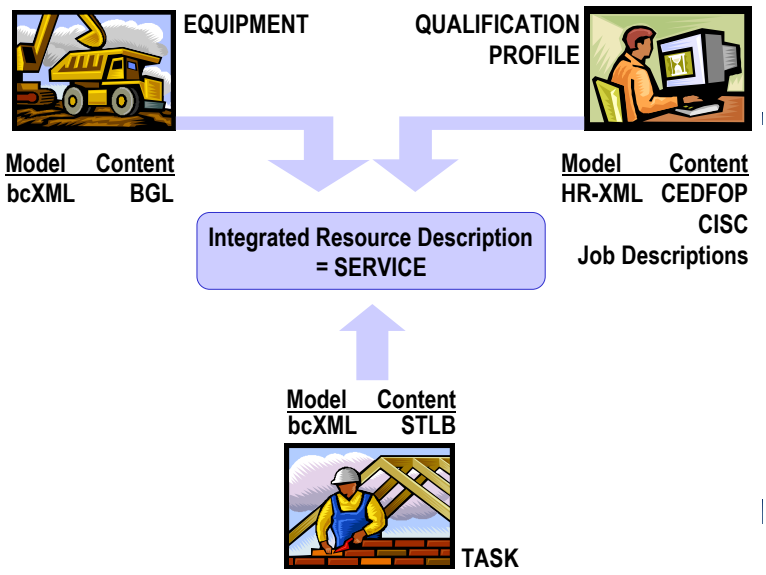

Figure 3: The Integration Process – Towards an Integrated Resource Description

Within the next sections the mapping and merging strategy, enabling and supporting the integrated usage of the existing, standardised, domain models and content descriptions, will be explained. The mapping and merging strategy will contribute to the development of a homogeneous description of the proposed Integrated Resource Description short called Services.

3.1 Syntactic Integrity

Harmonisation of data models, already on the conceptual level, is one key-issue in the standardisation process. Comprehensive methodologies have been developed e.g. within the ISO-STEP framework (see Burkett and Yang 1995 or Owen 1997). Katranuschkov 2001 analysed different sources and finally developed the following generalized steps:

(1) specification of fundamental, cross-sectorial concepts in resource schemata, (2) requirements analysis and conceptual design of domain models, (3) structural harmonisation of the separate domain models, and (4) merging of domain models into one consolidated schema.

3.2 Semantic Integrity and Content Integration

Researchers in the area of multi-dimensional information management as well as in the field of multiple databases have developed several approaches for the definition of integrated databases or partially harmonised databases (e.g. Anahory 1997 or Conrad 1997). Most of these approaches suggest the following integration strategy:

3.2.1 Pre-Integration Phase

Within that phase overlaps as well as missing descriptions according to the user requirements on the integrated model are determined. The degree of automation is very low.

3.2.2 Comparison of the Schemas

Within that phase conflicts between the schemas and within the content-descriptions are detected and documented. Furthermore, the different solutions are analysed and a preferred solution needs to be defined. The preferred solution describes the problem in the best way according to the individual problem specification.

3.2.3 Mapping
Within this phase the necessary integration steps are defined. It is described, how the separate contend descriptions must be transformed in order to become part of the integrated total information space. In Katranuschkov 2001 mapping patterns are defined on different levels: (1) on class level, (2) on instance level, and (3) on attribute level. Furthermore, the attribute level mapping patterns are classified into (3.a) basic mapping patterns, (3.b) complex mapping patterns, and (3.c) generative mapping patterns. The mapping phase can be partially automated.

3.2.4 Merging
Within this phase the different integration steps will be performed sequentially. The results will be checked and verified. After correct completion of each step the total merging process will be committed. This phase can be highly automated.

4 Example
Given the general approach in Chapter 3 we identified the following cases within the e-Sharing project.

4.1 Domain Specific 'Schema-to-Schema Mapping'
In case of the 'AEC-Equipment Domain' an existing modelling approach was mapped towards an information space (contend descriptions). Because it was decided to use only one existing source describing the content (BGL) there was no need to perform semantic integrity checks. However, it was necessary to harmonize the bc-XML syntactic model and the BGL-syntax with each other.

4.2 Domain Specific 'Content Merging'
In case of the 'AEC-Qualification Profile Domain' an existing modelling approach was mapped towards different content descriptions. Therefore, it was necessary to ensure intra-domain specific semantic integrity by analysing the different content descriptions. In our case we had to analyse descriptions of qualification profiles for Construction Engineering Personnel as well as the descriptions of qualification profiles for the different professions such as 'brick layers', 'roof-tilers', 'carpenters', etc.

Additionally, it was necessary to perform a syntactic harmonization between the existing HR-XML schema on the one hand and the already integrated content descriptions (CISC and the "German Job Descriptions") on the other hand.

An example in the AEC-Sector is the "roofer" competency description from the CEDEFOP (see Figure 4). It is necessary to analyse the attributes 'Competency Technologies,' 'Behaviour Skills,' and Technical Skills within the mapping process.

Competency:	*Roofer*
Technologies:	*Roof Bricks, Cladding, Timber Construction, Solar Systems, External Lighting Protection,*
Behavioural Skills:	*Attention to Detail, Communication, Teamwork, Languages*
Technical Skills:	*Car License, Forklift-Operator, Crane-Operator, Certified for Specific Systems*

Figure 4: Competency "Roofer" in AEC Sector from CEDEFOP

'Behavioural Skills' are soft skills and only usable as 'Supporting Information' in the HR-XML-schema. The 'Technologies' will be mapped in 'TypeDescription.' Both operations are a 1:1 mapping on attribute level. The 'Technical Skills' are real executable activities, like 'Crane-Operator,' this makes it in HR-XML to stand-alone competencies. Therefore, it is classified as an 'Attribute-to-Entity Mapping' (s. Figure 5).

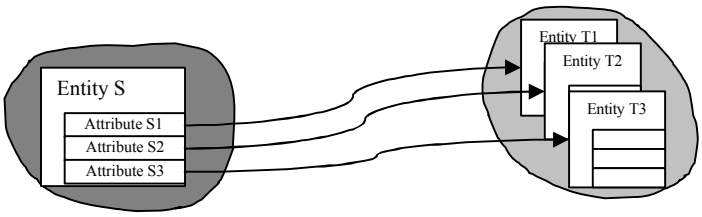

Figure 5: Attribute-to-Entity Mapping

Each attribute describing 'Technical Skills' will become a single (sub)entity. This entire group of sub-competencies results in HR-XML to a competency set 'Roofer' (s. Figure 6).

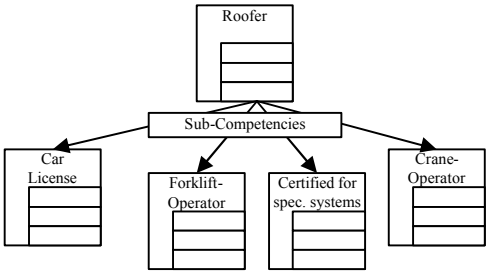

Figure 6: Competency "Roofer" with Sub-Competencies in HR-XML

Competencies in HR-XML are acquired from CEDEFOP and CISC. Thus, it might be possible that different terms for the same competency are used. The competency 'Car License' in CEDEFOP is called in CISC 'Driving License.' A manual merging between CEDEFOP CISC is necessary.

4.3 Cross Sectorial 'Schema and Content Merging'

After the harmonization of the intra-domain syntactic and semantic as well as the intra-domain information integration (Figure 7, step 1 through step 4) we have completed all the requirements for the most complex task – the cross-sectorial integration activities: the definition of 'Services.' Such complex service descriptions are necessary to support easy offer and order processes for the end-user, especially from SMEs in the AEC-domain.

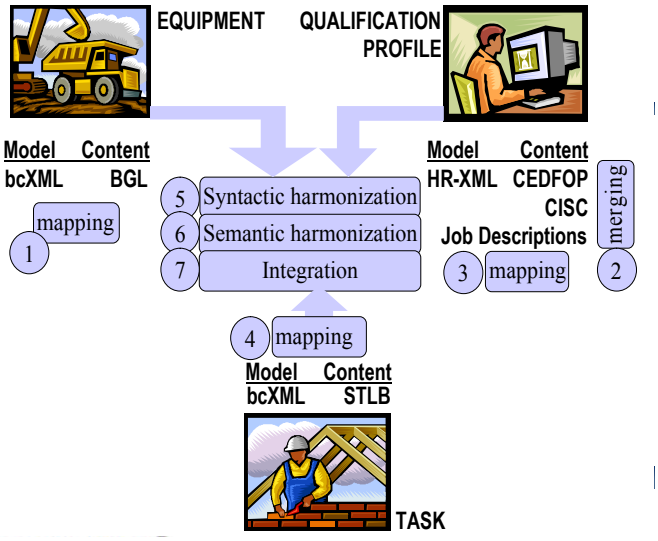

Figure 7: Overview of all mapping/merging activities within the example project

The following steps are currently performed in order to generate the model and the related information basis for the 'service descriptions.'
(1) Syntactic harmonisation between the 'construction equipment schema', the 'qualification profile schema' and the 'task schema' (Figure 7 step 5)
(2) Semantic harmonization between the 'construction equipment schema', the 'qualification profile schema' and the 'task schema' (Figure 7 step 6)
(3) Definition of mapping algorithms in order to define an integrated information space as 'federated information system' (Figure 7 step 7)

5 Usage Scenario of the Integrated Resource Description

To improve the efficiency of the e-Sharing system it will be possible to propose the lessee similar resources or tasks if the required resource is not available or it is possibly cheaper to rent a complete 'Service'. To provide this it is necessary to prepare in a first step a matching specification, which includes matching for the most common relations between resources and qualification profiles as well as tasks. For example a company needs a scaffolding the e-Sharing system can offer only the scaffold or the opportunity to lease the complete 'scaffolding service' by another company, which is a specialised company for scaffolding. Thus both participants can profit from the e-Sharing system, in case the scaffold company can erect the scaffold cheaper then the company, which needs the scaffold.

Another business scenario in e-Sharing is to offer specialized equipment like cranes or the equipment with certified operating personnel for required resources. To enable multiple usage of such matching profiles, it is the best way to store these matching specifications in a database. The first version of these matching specifications will be based on theoretical considerations. However, in reality more efficient matching specifications might be 'discovered'. Therefore, matching will be completed in a second step through an usage analysis of the e-Sharing system.

Usually, lessees have a clear understanding what type of resource to rent. However, in case the specific resource is not available they might wish to rent a complete service instead of a single piece of equipment. Therefore, it is desirable to document and analyse user decisions to allow for semi-automatic decision support features. Furthermore, it might be necessary to weight the matching criteria. This feature would support the creation of different decisions according to the project-specific requirements. Consequentially, each individual created offer can be upgraded to an extended standard offer by the system.

6 Conclusions

The clear separation into Meta-Description, Taxonomy-Description, and Content-Instantiation guarantees flexible usage and ensures further extension of our work results. The added value of the e-Sharing integrated resource modelling approach will be achieved by:
(1) integrating existing, standardised equipment and task descriptions,
(2) merging models and content descriptions with each other, and
(3) finally generating a generic, easy to use, integrated equipment and task specification.

This integrated approach will contribute to new ways of working by supporting easier co-operation in the construction sector. Furthermore, it supports the establishment of new organisational patterns, such as VOs, and therefore strengthens and extends the competitiveness of SMEs and the construction sector in general.

The integrated resource modelling approach is easily adaptable to other sectors and thus supports leasing-concepts on a cross-sectorial, international way.

7 References

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