Challenges in Procurement of Engineering Services in Project Business

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***Abstract*—In plant construction business engineering has an outstanding influence on project success. Thereby, a plant is usually provided by a general contractor as turnkey solution. However, to win these projects, the general contractor is depending on external engineering service providers. The reasons are e.g. missing expertise in non-core-competence activities, lack of staff or too high costs of internal personnel. Thus, specialized companies are offering engineering services. But purchasing and engineering services is a challenge, because there are many stakeholders with different goals. This paper analyzes the main characteristics and challenges in purchasing of engineering services. It is shown, that especially the description of the engineering demand is a key element. The contract design and the service execution are based on the specification of the demand. But due to time pressure and established structures the accuracy of specifications and with that the contract design is neglected more and more.**

I. INTRODUCTION

Within the German economy the machinery and plant construction business is an important branch with nearly one million employees [1]. Usually, the machines and in particular plants are customer specific solutions. They are engineered according to customer specific requirements. It is difficult to evaluate engineering´s contribution to project success [2] but most experts would agree that engineering has an outstanding influence on the project success. E.g. the high financial impact of errors in engineering underlines the need for high engineering quality [3].

Thereby, engineering is an intellectual activity with an immaterial result. Engineering is "*the application of scientific principles to the optimal conversion of natural resources into structures, machines, products, systems, and processes for the benefit of humankind*" [4]. This can be the design of a plant concept or calculations of mechanical and electrical parameters [5]. In project business engineering has substantially three phases: preliminary engineering (also referred to as concept engineering), basic engineering, and detail engineering [3]. Each phase is a step towards a more detailed specification of the final solution. These engineering phases can be parallelized partly. Prior to the engineering the basic requirements for the plant are determined. The engineering phase is followed by the construction and the commissioning phase (Figure 1).

Regarding industrial plant projects, engineering can be splitted up into project dependent and project independent engineering [3][6].

- Project dependent engineering (also order dependent engineering) comprises engineering activities that are carried out specifically for an end customer project.
- Project independent engineering (also order independent engineering) comprises the creation of reusable engineering artifacts or processes (e.g. software libraries).

Within these two areas, the engineering is divided into the abovementioned phases preliminary engineering, basic engineering and detail engineering [3][6][7] (Figure2).

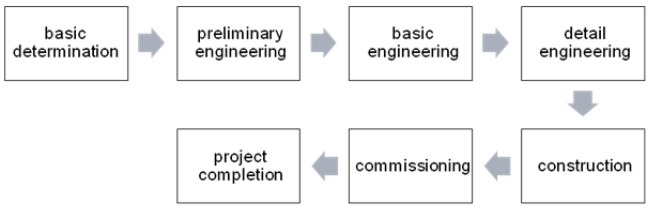

Figure 1: reference process for project business [3]

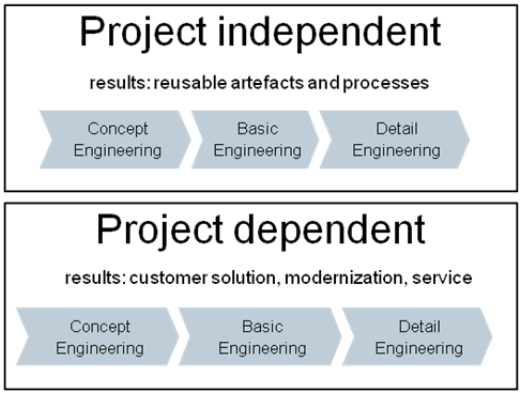

Figure 2: dependent and independent engineering

An industrial plant is usually provided as turnkey solution by a general contractor. This turnkey business is also called Engineering Procurement and Construction (EPC) or Engineering Procurement, Construction and Management (EPCM) business. Within such an industrial plant project several engineering activities in different engineering disciplines have to be done. This includes e.g. process engineering, software engineering, mechanical engineering. Depending on the project size an engineering manager, respectively the project manager, defines the working packages. Today, these engineering activities (hereafter called engineering services) are increasingly outsourced [8], what is reflected in the increasing revenues of engineering services providers. Engineering services can be provided within a company or for an external customer [5]. Here, the importance of external service providers and thus of a structured procurement process increases [9][10]. The spectrum of engineering service providers is ranging from freelancers

("one-man companies"), medium and small sized companies to corporations, with own service sectors, that offer internal and/or external engineering services. The turnover of leading German engineering service providers has grown by almost 20% from 2010 to 2011 [11]. The segment is expected to grow by more than 6% annually until 2020 [12][13]. The reasons for outsourcing are e.g. the increasing plant complexity, financial risks, the variability of orders or personnel bottlenecks [14][15]. But what is an engineering service? There is no common definition for engineering services, as is shown below. Thereby, a common definition is the first step towards a standardization of engineering services. Finally, service standardization creates transparency about the scope of services [16] and is a component for a better procurement of services [17]. In general, the procurement of services (including engineering services) is more difficult than the procurement of goods [18]. The challenges in purchasing engineering services are the focus of this contribution. In this context we set our priority on the aspect of definition and standardization of engineering services.

II. ENGINEERING SERVICES

In this section the results of the desk research about the definition of engineering services are summarized. This includes definitions in economical classifications, institutional definitions, and definitions in scientific publications. In conclusion, five economical classifications were found and investigated. On the institutional side, only two definitions were found. The research papers and scientific works were identified in two scientific databases.

A. Economical Classifications

The New Mexico Statutes (2006-2013) are a national classification for New Mexico, United States. They define engineering services as follows: "*'Engineering services' means any service or creative work, the adequate performance of which requires engineering education, training and experience in the application of special knowledge of the mathematical, physical and engineering sciences to such services or creative work as consultation, investigation, evaluation, planning and design of engineering works and systems, engineering studies and the review of construction for the purpose of assuring substantial compliance with drawings and specifications; any of which embrace such services or work, either public or private, in connection with any utilities, structures, buildings, machines, equipment, processes, work systems, projects and industrial or consumer products or equipment of a mechanical, electrical, hydraulic, chemical, pneumatic or thermal nature, insofar as they involve safeguarding life, health or property, and including such other professional services as may be necessary to the planning, progress and completion of any engineering services. Such practice includes the performance of architectural work incidental to the practice of engineering. 'Engineering services' does not include responsibility for the superintendence of construction, site conditions, operations, equipment, personnel or the maintenance of safety in the work place.*" [19]

The North American Industry Classification System (NAICS) (2012) is a North American business and government classification. It lists engineering services as no. 541330 in "Professional, scientific and technical services (54 / 541)" in the category "Architectural, engineering and related services" (5413). It is defined as follows: "*This Canadian industry comprises establishments primarily engaged in applying principles of engineering in the design, development and utilization of machines, materials, instruments, structures, processes and systems. The assignments undertaken by these establishments may involve any of the following activities: the provision of advice, the preparation of feasibility studies, the preparation of preliminary and final plans and designs, the provision of technical services during the construction or installation phase, the inspection and evaluation of engineering projects, and related services.*" [20] For illustration the following eight examples are listed: civil engineering services, consulting engineering services, electrical and electronic engineering services, industrial engineering services, mechanical engineering services, mining engineering services, petroleum engineering services, traffic consultants, engineering services. A list with *all examples* lists 23 additional examples: acoustical engineering consulting and design services, aeronautical design services, boat engineering designing services, chemical engineering services, combustion and heating engineering consultants, construction engineering services, electrical engineering services, electronic engineering services, engineering design services, engineering services, engineers, private practice, environmental engineering services, erosion control engineering services, forestry consultants (own account engineering), geological engineering services, geophysical engineering services, logging engineering services, marine engineering services, office of engineers, solar energy units (designing), telecommunications engineering consulting, transformer engineering services, transportation consultants (consulting engineering). Additionally the NAICS has listed the following exclusions: design and construction of buildings, highways and other structures (see 23 Construction), providing construction management services - classified by type of construction (see 23 Construction), gathering, interpreting and mapping geophysical data (see 541360 Geophysical surveying and mapping services), providing engineering surveying services (see 541370 Surveying and mapping (except geophysical) services), creating and developing designs and specifications that optimize the function, value and appearance of products (see 541420 Industrial design services), planning and designing computer systems that integrate existing hardware, packaged or custom software and communication technologies (see 541514 Computer systems design and related services (except video game design and development)), providing advice and assistance to others on

environmental issues, such as the control of environmental contamination from pollutants, toxic substances and hazardous materials (see 541620 Environmental consulting services). [20]

In 2010 The World Bank refers to the Provisional Central Product Classification (CPC) (1991) [21]. According to this definition engineering are divided into engineering services and integrated engineering services: "*Engineering services (CPC 8672): covering (1) advisory and consultative engineering services, (2) engineering design services for the construction of foundations and building structures, (3) engineering design services for mechanical and electrical installations for buildings, (4) engineering design services for the construction of civil engineering works, (5) engineering design services for industrial processes and production, (6) engineering design services not elsewhere classified, (7) other engineering services during the construction and installation phase, and (8) other engineering services. Integrated engineering services (CPC 8673): covering (1) integrated engineering services for turnkey transportation infrastructure projects, (2) integrated engineering and project management services for turnkey water supply and sanitation works projects, (3) integrated engineering services for the construction of turnkey manufacturing projects, and (4) integrated engineering services for other turnkey projects.*" [22]

The United Nations (UN) released the International Standard Industrial Classification of All Economic Activities (ISIC), Rev. 4 in 2008. Engineering services are mentioned in "*7110 Architectural and engineering activities and related technical consultancy*". With reference to engineering services a category "engineering design" is listed with applying physical laws and principles of engineering in the design of machines, materials, instruments, structures, processes and systems and consulting activities as examples. [23]

B. Institutional Definitions

The Association of German Engineers (VDI) defines engineering services as "*independent and market-able services. They are connected with providing and utilization of competencies, which are mostly based on engineering-services, knowledge, and engineering experience in practice. Within the development- and creation processes of engineering-services internal as well as external factors are worked on with the objective of having a benefiting effect on external factors, like people and objects. Services can be provided for internal and external customers. Service as defined by this guideline is an activity, which is instructed and paid by a customer/user, who in return acquires an immaterial service as a result of the activity – e.g. calculation of a bolted joint, plant installation, process analysis, and project planning.*" [5]. Commissioning, maintenance or construction is excluded. In two further publications engineering as a service is mostly connected with personnel services [24][25]. Factory agreements are considered critical [25].

The European Committee for Standardization (CEN) distinguishes between engineers' activities and engineering services. Engineers' activities are defined as intellectual activities which are necessary for the definition, the design, the manufacture, maintenance and recovery of a product, a process, a building or an industrial plant. Engineering services are defined as intellectual activities that are performed by specialized (or specially trained) professionals in any or all sections of the life cycle of a product, a process, a building or an industrial plant [26][27][1]. An according standard was published by the German Institute for Standardization in 2013.

C. Scientific Research

In addition to the targeted search in institutional publications we performed a literature review. Research papers and scientific works were searched in the two scientific databases IEEE Xplore and ScienceDirect (Table 1). For the search the expression `"engineering services" OR "engineering service"` was used. Within the results the terms `"typology"`, `"classification"` and `"definition"` were queried independently. All publications until 2013 were included.

TABLE 1: LITERATURE REVIEW

Database[2]	engineering service(s)	+ typology	+ classification	+definition
IEEE Xplore	397	0	3	5
ScienceDirect	156	4	18	36
Total	553	4	21	41

Since only a very small number of results is found for the in-result search all 553 publications were inspected by title and abstract. In this inspection it was omitted, that none of the studies focused on definition, classification or typology of engineering services. 56 publications were selected for a detailed analysis of the full paper. Most of the papers are not relevant to the research topic. In several cases the topic was "service engineering" and not the "engineering services". Eight publications are about engineering education and further six are about quality of engineering or business strategies. But none of these papers discussed the scope and definition of engineering services in detail. Just five of those publications were identified as relevant for the topic [28][29][30][31][32]. The content of these definitions is discussed in the following. Besides these papers due to citation analysis and review of publications about industrial and knowledge-intensive services in general, further information was identified [33][34][35][36][37][38][39][40] [41][42]. This first result underlines, that there is little research about the definition of engineering services.

Regarding the results of that research, a wide definition is that "*Engineering Services include a wide range of activities,*

[1] The CEN-definition has been adopted in the corresponding standards of the German Institute of Standardisation (DIN).

[2] Configuration for databases: IEEE Xplore: search in metadata only; ScienceDirect: search title, abstract, keywords

essentially intellectual, which are combined to optimize investment decisions in terms of choice, design and project management and implementation." [29] Furthermore, it is written, that there are three different markets for engineering services: Construction (buildings), Infrastructure (roads, railways, …) and Manufacturing (also referred to as Industrial Engineering Services) [29]. The clients of engineering services are integrated in the service delivery process and involved in the decision making process [31][33]. Engineering services are mostly carried out in projects and because each project is unique engineering services are potentially unique [31][34]. They include, for example, the design of instruments, plan activities, analyze requirements, produce drawings, obtain approvals, resolve conditions of contract, check that the cost plan is still valid [30][32]. The outcome of engineering services has tangible parts (e.g. drawings) and intangible parts (e.g. client satisfaction) [31]. Engineering as a service can be assigned to end-user's process-oriented services (also called added-value related services) [35][36]. With this classification engineering is defined as industrial service [35][37]. On the one hand, industrial services in general are defined as services by manufacturing companies [37]. On the other hand, there is the picture of industrial services in the broader sense as services with investment-related clients and industrial services in the narrow sense as product-related services [38]. In this context, engineering services are industrial services in the broader sense. However, engineering services can be seen as intellectual activity, associated to knowledge-intensive services [39][40][31].

Errors in engineering can surely result in high subsequent costs [30]. Hence, the provision of engineering services requires an extensive education and training [30][31]. They are provided by engineers or consultants [30][32]. Even when a university degree is the most common qualification, an alternative technical qualification is possible [41]. Regarding the technological field there are several engineering fields and disciplines [42] and many engineers, respectively, engineering service providers, are specialized on one area [28][30][31].

D. Summary „Definition of Engineering Serivces"

The presented definitions give an impression of the difficult task of a general definition of engineering services. The NAICS provides a so-called *full list of examples* with 31 engineering services. But even one of these (for example mining engineering services) can cover a wide range of activities as listed by the VDI, the New Mexico Statues or the CPC (planning, design, process analysis…). On one point, however, there is a substantial consensus; a special education or a special experience level is necessary to perform engineering services. In general the following characteristics of engineering service can be derived:

- An engineering service is an intellectual activity. It means to apply principles of engineering in a creative work to evaluate, investigate, plan, consult, design, develop or utilize an outcome.
- The outcome of engineering services includes rather tangible commodities and intangible parts.
- Engineering services can be allocated to industrial services in the broader sense.
- The application of engineering services requires a special education, but not necessarily a university degree.
- Mostly, engineering services are provided as temporary employment or personnel service.
- Engineering services refer to at least one engineering discipline.
- There are three different markets for engineering services: Construction, Infrastructure, and Manufacturing.
- Subject of engineering services are machines, materials, instruments, structures, processes, systems and turnkey manufacturing or infrastructure projects.

III. SOURCING ENGINEERING SERVICES

Since there is not much research in this specific context, this work is based on a qualitative approach. Therefore explorative expert interviews were conducted. In total 12 guided interviews with engineers, engineering managers and service managers were conducted (see table 1). Because of the broadly scattered interview partners, a half standardized questionnaire was used. The interview results were analyzed and interpreted based on the qualitative content analysis according to Mayring [43]. The results were assigned to inductively created categories like 'engineering demand', 'supplier selection' or 'contract management'. Based on this data, some of the challenges in procurement of engineering services were identified.

A. Engineering Demand

Usually, the engineering demand is defined by the engineering manager, respectively, the lead engineer or project manager[3]. The defined engineering activities are executed by the project department itself or obtained from internal or external service providers. This service is based on the description of the demand.

In a material procurement process the specification of the demand is communicated to the purchasing department. This could be a copper cable of a specific alloy, cross section, length, insulation and temperature resistance for instance. With this information, the purchase manager can order the material for matching quality and best price. On one hand, this specification must contain all information so that the purchase manager can search for a proper supplier. On the other hand, the supplier must evaluate whether he can deliver the product. In the procurement of material, the purchasing department can operate autonomously based on standards and technical

[3] Depending on the project size there is a project manager for the project engineering and an additional engineering manager / lead engineering for the technical engineering. In smaller projects both jobs are done by the same person. Hereafter called engineering manager.

specifications. Due to their intangibility the specification of services is more difficult.

At an early time of a project, systems and work packages are often not fully elaborated, which is associated with unclear requirements of the end customer. The requirements of the project are not stable and may change during the project. The project specification, as a basis for further planning, is developed in several repetitive cycles in which the customer requests for changes are integrated. Thereby, it is difficult to describe the scope of specific working packages beforehand.

In particular, the time pressure causes that the engineering activities are just outlined and will be awarded to well-known companies that are incorporated into the project type and create a result "on call". The long-term collaboration with a service provider can lead to less accurate descriptions, since the quality of service is known and the service provider is incorporated. In some cases he has a better understanding of the real demand than the EPC provider or the end customer. It was reported, that the delivered solution often differs from the request, because the service provider has more knowledge about the technology than the customer. If something goes wrong, e.g. due to time pressure, the documentation can be different from the final solution.

Regarding the procurement process, the reuse of specifications is difficult, because the experience is missing in case of new plant types and the differences between individual plants of the same type can be so high that reuse is difficult. In many areas, the opinion predominates "before I create a precise specification, I can do the job on my own." Therefore, provision of personnel on a temporary basis is often used in order to get a flexible workforce – based on competencies and not on a detailed specification of the demand.

In practice, the requirements are often negotiated between the engineering manager and an engineer from the service provider. The service is then bought by the project procurement "as previously agreed". As a reason for this proceeding the missing technical understanding of the purchase managers was mentioned.

A problem in this context is that the requirements of the plant itself are not well defined. The customer usually has a technical expert, which can be an employee of the end customer himself, or an external consultant. An often quoted contract phrase is that "the engineer of the customer must be satisfied". This is makes the engineering of a machine or plant very difficult, as the consultant can change between two familiar projects of the same end customer. Further, each consultant has different priorities and different knowledge of technological details. Also, the requirements of external advisers are named as major hurdle because they are difficult to assess and they can change quickly.

We see signs that the understanding of the scope of engineering services differs strongly between engineering and procurement (Figure 3).

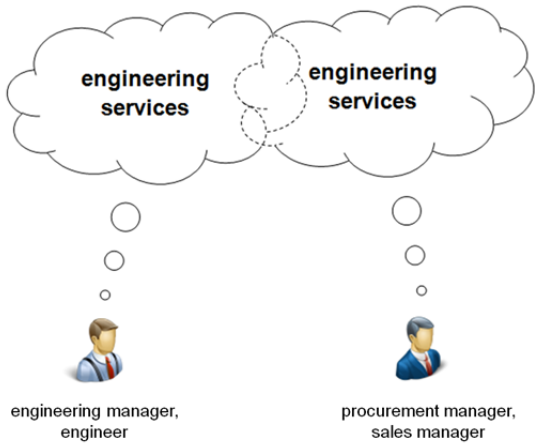

Figure 3: Different understanding of engineering services

B. Solutions vs. Services

The description of services, however, is more difficult due to the specific service characteristics, such as immateriality and intangibility. In terms of engineering as a service, the demand can be a pure service, a bundle of services or a customer specific solution. Engineering service providers are not just service providers but solution providers. Instead of buying individual services or components, the purchase of modular systems or solutions reduces the interfaces and thus the complexity of the project.

For example, the engineering of a steel construction can be purchased separately or together with the construction service and the material. An engineering service in context of factory automation can be software programming for a process control or a full PLC system including integration in the plant concept, installation and commissioning.

In order to minimize the complexity within a project it is attempted to keep the number of suppliers per engineering discipline as low as possible. This results in the purchase of systems or solutions instead of services and components.

C. Supplier Selection Process for Engineering Services

For engineering managers the problem solution has the highest priority. The purchasing of a service provider or a solution shall cause as little work as possible and the cooperation process shall be very flexible. The operative procurement process is handled by the purchasing department. But in contrast to purchasing of materials there is usually no central service purchasing process. This results in maverick buying and leads to a high number of service providers, because every project selects the services on its own. This can result in ten-thousands of service providers (worldwide) with small revenue per order. However, unlike "classical maverick buying", the selection of the service providers is not done by the respective purchasing department, but by the respective engineering managers, mostly based on established relationships. A well-known service provider is preferred, because the quality is known. If a company once sent "a good

man", who produced good results, that company, preferable that man is hired again.

Additionally the induction phase can be omitted. The induction phase can comprise the period of a complete plant construction project and includes e.g. the incorporation in processes, technologies, tools or standards.

As mentioned above, in case of long term relationships, the accuracy of job specifications can become less accurate, because the engineering manager is already convinced of the performance of the service provider – and the service provider has worked in familiar projects already. If the service provider is incorporated, the distribution of tasks can be done "on call" respectively "like last time". This is a popular approach, since there is always time pressure in plant projects.

However, some interviewees state that this kind of purchasing can lead to dependencies from service providers, high costs because of missing comparison/ competition and finally to inflexibility, especially if the service providers are small companies. In this case a sick employee of the service provider or other jobs can interfere with the own projects. Most of these concerns are rejected because the follow-up costs of engineering errors and delays are not foreseeable. In result a higher price for engineering services is accepted. Besides the abovementioned need for quality, the familiarization phase, which goes along with a know-how transfer to the service provider, for new service providers is a main reason for the fall back to well-known service providers.

An argument mainly presented by the procurement managers, but agreed by the engineers is that the engineering manager often has no knowledge about other service providers, which are capable for the job and maybe better (price or qualification) than the well-known ones. Only if there is no known service provider, which complies with the requirements, a request is made to the procurement department. An example is the need for a special technical skill. Furthermore, the requirement for regional suppliers is mentioned. Especially in projects from the public sector, there are specifications about the share of local suppliers and service providers.

Usually, new service providers are "tested" in small projects or with small work packages. Later on, they are used in wider scale. Due to these conditions, usually the engineering manager selects the engineering service providers.

D. Internal vs. External Engineering Service Providers

Usually, activities in core competence areas are sourced internally. Targets of internal sourcing are a high utilization rate of internal workforces and the avoidance of supplier dependencies. Especially the allocation competence for a plant must be kept available in the company respectively the department. If an engineering activity was not executed for several years the existing know-how may get lost. This happens e.g. with the change to a new technology. The advantages of internal service providers are know-how protection, high flexibility of internal workforces and predictable quality respectively trust in internal service providers. Moreover, internal employees know the internal processes and the companies' technology. For internal services service contracts are the preferred contract type.

The reasons for external sourcing are missing personnel/workforce, missing know-how or competences (maybe outside of business focus) or most frequently named: to high costs of internal service providers. External service providers have a broad range. Some service providers are specialized in a small field of technology; other service providers have a broad field of competences. There are companies specialized on personnel services (service contracts and temporary employment) and solution providers with product-service-systems.

A special challenge is the sourcing of single engineering service due to the end customer. He can provide services by himself (end customer internal) or procure services from external service providers (end customer external).

E. Contract Management for Engineering Services

Instead of creating comprehensive work contracts where the results are specified in detail, a flexible contract is preferred by engineering managers. The "make the customer happy" phrase from the end customer contract is handed over to the service provider. In some cases it was mentioned, that the engineering service provider did different work than defined in the contract. The reason was that the specification in the contract would not work. It was specified that even the documentation was not adapted in some cases.

A better solution would be the work with work contracts with a specified scope and outcome. This provides a defined amount of work and liability about the outcome. However, this is difficult for engineering services in plant construction (why). Moreover, the take-over of the liability by the service provider hardly plays a role in the industrial practice because the financial possibilities of small companies are restricted. The risk therefore lies with the EPC provider, even at the obtaining of engineering services with work contracts. Work contracts mean a high planning effort just at the project beginning. In addition they are little flexible. The exact result should be defined in the contract. However, the result frequently differs from the specification in the contract in the practice. Changes aren't documented properly or additional activities arise. Employee cession or service contracts are a solution. But they provide less contract safety. In Germany, temporary employment requires a special allowance which is regulated by the according law. Additionally personal placement brings along the danger of the disguised employment. It therefore happens frequent in the practice, that fake manufacturing contracts are used. Not faked to circumvent laws, but faked to have a fixed pricing for a flexible performance which is difficult to be defined.

F. Summary „Sourcing of Engineering Serivces"

In result there are several characteristics and challenges about the procurement of engineering services in project

business. The following characteristics and challenges apply for the EPC contractor in general:

- There is no common understanding, no uniform terminology for engineering services. This complicates the specification of the demand.
- Service providers are distributed globally. Reasons are low cost but also specifications of the customers. It is difficult to find local service providers. In addition, cooperation is more difficult because of language barriers and long communication paths.
- The perception of service quality is subjective. This makes the objective selection and the rating of service providers more difficult.
- Know-how drain and dependence on external service providers must be avoided. Thus, activities from the core know how area shall not be outsourced.
- The availability of the service must be ensured. Thus, it is important to know more than one capable service providers for important services.
- The system is based on strong relationships and knowledge of the individual. The loss of a central employee is a risk. This
- The procurement department usually has not the competence to select matching service providers. Thus, the engineering selects the service providers. This is often done on base of experience.
- Time pressure and the demand for high quality exclude "experiments" with new service providers because new service providers must be incorporated. Usually they are tested on smaller tasks or projects before they get central tasks.
- There are too many service providers, especially in the C range with little volume. A proper supplier management could reduce costs and risks.
- Perhaps the engineering knows no better / cheaper suppliers.

To analyze the missing common understanding for engineering services the portfolio of engineering service providers is investigated in the following chapter.

IV. ENGINEERING SERVICE PROVIDERS

In this section the understanding of the scope of engineering services is investigated from the point of view of engineering service providers. Therefore, the portfolio of the 24 largest engineering service providers in Germany [11] is analyzed. The scope of the research was in the companies' understanding of the scope of engineering services. Building upon these insights the range of engineering services is analyzed.

A. Types of Engineering Service Providers

Engineering service providers can be differentiated in solution, service, and personnel providers. E.g. *IndustrieHansa* presents itself specifically as a provider of engineering services [44], while the *P3 group* focuses on engineering solutions [45]. A total of 15 (63 %) service providers describe themselves as (engineering) solution providers (Table 2). They provide customer specific engineering solutions, including product-related services like construction and commissioning. Examples are complete systems to be integrated in a machinery or plant, e.g. a process control including hardware, installation and commissioning. Seven (29 %) of the companies regard themselves as engineering service providers and two (8 %) companies describe themselves as providers of personnel.

TABLE 2: SELF-CONCEPT OF ENGINEERING SERVICE PROVIDERS

Company	Self-Concept		
	Personnel	Service	Solution
Bertrandt AG			x
IAV GmbH Ingenieurgesellschaft Auto und Verkehr			x
EDAG GmbH & Co. KGaA			x
Ferchau Engineering GmbH		x	
MBtech Group GmbH & Co. KGaA			x
ESG Elektroniksystem- und Logistik GmbH		x	
Brunel GmbH,	x		
Randstad Professionals GmbH & Co. KG	x		
Euro Engineering AG, Ulm			x
IndustrieHansa Consulting & Engineering GmbH,		x	
Bright ONE			x
P3 Ingenieurgesellschaft mbH			x
MVI Group GmbH,		x	
Rücker AG		x	
IABG Industrieanlagen-Betriebsgesellschaft mbH			x
Assystem Deutschland Holding GmbH			x
Altran GmbH & Co. KG		x	
FEV GmbH		x	
Semcon Holding GmbH & Co. KG			x
Alten GmbH			x
RLE International Gruppe			x
ETAS GmbH			x
Gigatronik Gruppe			x
Safran Engineering Services			x

But this is no hard division between these three types of companies because a solution provider in this context can also provide pure (engineering) services. Additionally, a company with the self-concept of a service provider can define a solution as a service. Furthermore, providers of personnel provide personnel solutions. In connection with this, the companies offer different types of contracts. In some cases the wording explicitly differs between personnel placement, temporary employment, service contracts and work contracts [46].

This finding about the self-concept of engineering service providers shows, that the portfolio of an engineering service provider is understood in different ways.

B. Characteristics of Engineering Services

Only four of the 24 engineering service providers specifically offer 'engineering services' as a service

[47][48][49][50]. Six other companies at least use the term 'engineering service' in companies' description or the description of the range of their services [45][46][51][52][53][54]. In part the other companies offer or describe engineering, services, solutions, products or similar, but not specifically 'engineering services'. Table 3 shows the descriptions or characteristics which were found under the topic engineering services. This is not a clue, that the other companies are no engineering service providers, but it shows that the term engineering service is not widespread; respectively there is no clear definition for engineering services.

Several characteristics of engineering services can be seen in these few descriptions. The most widespread characteristics that nearly all companies attribute to themselves are (engineering) experience and specialization in engineering disciplines or industries. These attributes seem to be basic attributes for an engineering service provider. Additionally, most engineering service providers market themselves as innovative partners. A good partnership and innovative solutions seem to be essential too.

Regarding the service spectrum, Bertrandt, for example, offers engineering services as specific service beside 13 other types of service. FEV on the other hand, lists engineering services on a high level with 14 subtypes of services. While FEV, P3, and MVI differ between management services and engineering services, Bertrandt considers project management as part of their engineering services. But the most of the engineering service providers do not use the term engineering service for their offerings. It is noticeable, that many companies offer solution packages. They offer services, covering the complete development- or life-cycle of a solution or a product. This includes product-related or value-add services. They emphasise that the solutions are integrated customer specific solutions. Many offerings go beyond pure engineering. Particularly project management is often part of the range of services, even if it is separated from engineering services in some cases.

TABLE 3: EXCERPT OF ENGINEERING SERVICE DEFINITIONS

	Company	Description / Characteristics of Engineering Service
Engineering services as service offering	Bertrandt AG	As range of services Bertrandt lists Design Services, Interior, Vehicle Body, Powertrain, Chassis, Simulation, Electronics, Modelling/Rapid Tech., Testing, Engineering Services, Commercial Vehicles, Aerospace, Trainings and other industries. Engineering services are described as follows: "*Increasing quality requirements and high process reliability play a major role at car manufacturers and automotive suppliers. Bertrandt's Supporting Services are designed to meet precisely these challenges. We support our customers by taking care of the interfaces outside the pure development process. Our range of services is divided into four main areas of expertise: project management, quality management, process validation and logistics*."
	ETAS GmbH	ETAS describes itself as development partner who offers the full range of its qualified employees' expertise. ETAS is specialized in automotive and offers services "*in all phases of the V-cycle to design, implement and operate development environments of customers for their benefit with capabilities extending beyond existing ETAS products*." ETAS mentions its comprehensive professional knowledge regarding processes, methods and tools used in the field of automotive software engineering. Under engineering services ETAS offers for example, support in the definition of processes, design and creation of customer specific solutions (including software and hardware developments), optimization of ECU code, integration of ETAS tools and solutions into customer specific development environments, customer specific extensions of ETAS software and hardware, integration of customer's hardware into ETAS software, linkage of customer's databases to ETAS software, direct assistance in the use of tools and solution, long-term maintenance of legacy tools and solutions still in use, and customer specific training. ETAS differs between engineering services, consulting, training, and support.
	FEV	FEV lists the following topics under engineering services: Passenger Car Diesel Engines, Passenger Car Gasoline Engines, Commercial, Industrial and Large Bore Engines, Transmissions, Turbocharging, Vehicle Engineering, Chassis Engineering, Electrical Systems and Electronics, Vehicle Electronics, Infotainment and Telematics, NVH – Noise Vibration Harshness, Advanced and Special Applications, Production & Value Engineering. All those "services" are described in more detail in the linked website.
	Semcon Holding GmbH & Co. KG	Semcon claims to provide engineering services worldwide, covering all the challenges in the development cycle, from idea to finished product. They offer expertise and resources.
Context information about engineering services	Assystem Deutschland Holding GmbH	The services portfolio of Assystem includes traditional development in the areas of design and analysis, as well as, qualification services, quality and project management and production-related engineering services such as production control, material technology and test engineering.
	MVI Group GmbH	The MVI Group differs between expert management and engineering services to the mobility industry.
	P3 Ingenieurgesellschaft mbH	P3 differs between international management consulting and innovative engineering services.
	Rücker GmbH	Rücker does not specifically mention engineering services but describes itself as leading global supplier of engineering services with offices all over the world. They are specialized in the automotive (car and commercial vehicles), aviation and railway industries. The services cover the entire production process chain and their employees are highly motivated and experienced experts. The service spectrum ranges from advisory/ consultancy to solutions including project responsibility. They claim to act as technology and innovation trendsetter.
	Randstad Professionals GmbH & Co. KG.	An engineering service provider develops new products, new processes or new production methods together with our customers. Randstad has expert kno-how in all engineering disciplines, in project management and in technical consulting. An engineering services provider helps the customer to optimize his personnel costs.
	Safran Engineering Services (subsidiary of Labinal Power Systems)	Safran provides dedicated system engineering design and technical analysis services worldwide to the aerospace, automotive, rail, and ground transportation industries. The services "*cover the complete cycle of activities including drawing up requirements and specifications, preliminary and detail design, engineering, conceptual work, system architecture, through to validation, testing & verification and technical publication*." The range of services covers technical assistance to full work package responsibility from the conception and development to integration and test. They take part in research projects and feasibility studies to large scale series projects. Safran mentions over 25 years of experience and describes itself as major partner for OEM and Tier One Supplier companies. They work as Risk Sharing Partner with Labinal Power Systems.

C. Summary "Engineering Service Providers"

The importance of engineering services is undoubtedly increasing. They are omnipresent in industrial environment. But there is little research in this field. In the abovementioned definitions engineering services are mostly associated with the engineering as activity. An engineering services is seen as engineering as a service, often understood as personnel service or temporary employment. In contrast, engineering services in the industry are mostly seen as solutions. The self-concept of most engineering service providers is not the concept of a personnel service provider but that of a solution provider. They offer a broad range of offerings *around* the engineering. This includes industrial and product-related services as well as consultancy or training. Besides the services the service providers partially provide the hardware running the engineered system. Additionally some engineering service providers produce prototypes or small series of engineered products. The borderline between engineering services, consultancy, management services, engineering solutions, and industrial services is blurred. Hence, it is obvious that the term 'engineering service' is not well defined.

There is substantial consensus that a special education, respectively, a special experience level is necessary to perform engineering services. While the definitions in economical classifications mainly refer to the service and an intangible result, the engineering service providers offer solutions comparable to product-service-systems. In this context the service providers offer different types of contracts in accordance with the requirements of the customer. It has likewise become clear that engineering is connected to a certain discipline, and most engineering service providers are specialized in a few disciplines.

V. CONCLUSION AND OUTLOOK

In result, the following characteristics can be assigned to engineering services:

- To core of an engineering service is an intellectual activity. It means to apply principles of engineering in a creative work to evaluate, investigate, plan, consult, design, develop or utilize.
- Engineering services range from engineering as a service (service contract), through engineers' services (temporary employment) to engineering solutions (work contract).
- Engineering services refer to at least one engineering discipline.
- Engineering services can be allocated to industrial services in the broader sense.
- The application of engineering services requires a special education, but not necessarily a university degree.
- Mostly, engineering services are provided as engineering solution familiar to a product-service-system. An engineering service can include services and possibly products connected to the engineering itself.
- Subject of engineering services are machines, materials, instruments, structures, processes, systems and turnkey manufacturing or infrastructure projects.
- The outcome of engineering services is mostly intangible (for example the process itself, the customer satisfaction or the quality of the plans, digital results) but can have tangible parts (e.g. prototypes).

Today engineering services are mostly specified by the potential and process dimension. What is necessary to perform an engineering service and what are the activities. Regarding the three contract types of engineering services this is connected to temporary employment or personnel services. A shift to the result of engineering services could be done by the use of work contracts.

A common definition of engineering services can help to structure e.g. procurement processes. Service standardization is an upcoming topic, but most researchers use common services like gastronomy, hair cutting or banking in their investigations. These services are familiar to everybody and with this more tangible. Further research, especially about the scope of engineering services, the challenges in engineering service operations can help to improve the planning and execution of industrial projects.

A major challenge in sourcing of engineering services seems to be the specification of the engineering demand and its communication from the engineering manager to the procurement. By a standardization of services it is possible to reduce the time for definition, planning and procurement of services. While the standardization of services in general is on the advance [55], engineering services are rarely investigated. But the procurement needs a specification that allows the autonomous purchase, as in the procurement of materials. Standardized services simplify the procurement process and enable make the scope of service transparent [16][56][57][58]. In this context a standardization of engineering services could help to simplify the procurement and planning process for engineering services. Both the engineering, as well as the procurement can benefit.

The proper planning of engineering services is a major challenge in plant construction business. There are several parties involved with different interests and points of view. An early involvement of the engineering service provider increases planning security about capacities and utilization. But at an early project stage the working packages are not defined in detail. These points lead to the fact that engineering services are often purchased as temporary employment or service contract to be flexible and simultaneously to have little work with contract design. But it seems that there are no universal competence profiles for engineers [41]. In case of work contracts the definition of the outcome is very general and probably the real outcome has different technical characteristics.

An impression is that the procurement process of engineering services is a maverick buying process. The difference to a "usual" maverick buying is that not the

procurement department selects the supplier, but the respective engineering department. A common description (purchasing, engineering, service providers) for engineering services is missing. The common understanding of engineering services is the first step towards more transparency about engineering services (Figure 4).

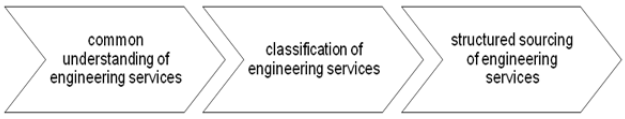

Figure 4: procedure model for optimization of engineering service sourcing

Based on a classification and typology of engineering services, a structured or centrally controlled purchasing process could be implemented (Figure 5). On the one hand a structured procurement process with defined standards for the scope can help to the best matching service provider. On the other hand it predefined templates for work packages and defined processes can help to simplify the planning process and thereby relieve the engineering manager. If a service provider has no matching resources replacement can be found faster.

Further research should analyze the portfolio of more engineering service providers, the engineering competences and working packages in project business, to find possible approaches for a better definition and a classification of engineering services.

VI. LIMITATIONS

This research is refers to information from the German industry. The qualitative part of work is based on 12 interviews. Even when the interviewees were selected from a broad field of hierarchical positions and job fields, only employees of one EPC company and two different service providers were included. Furthermore only one procurement manager was interviewed. A deeper analysis, especially from the point of view of the procurement department is necessary.

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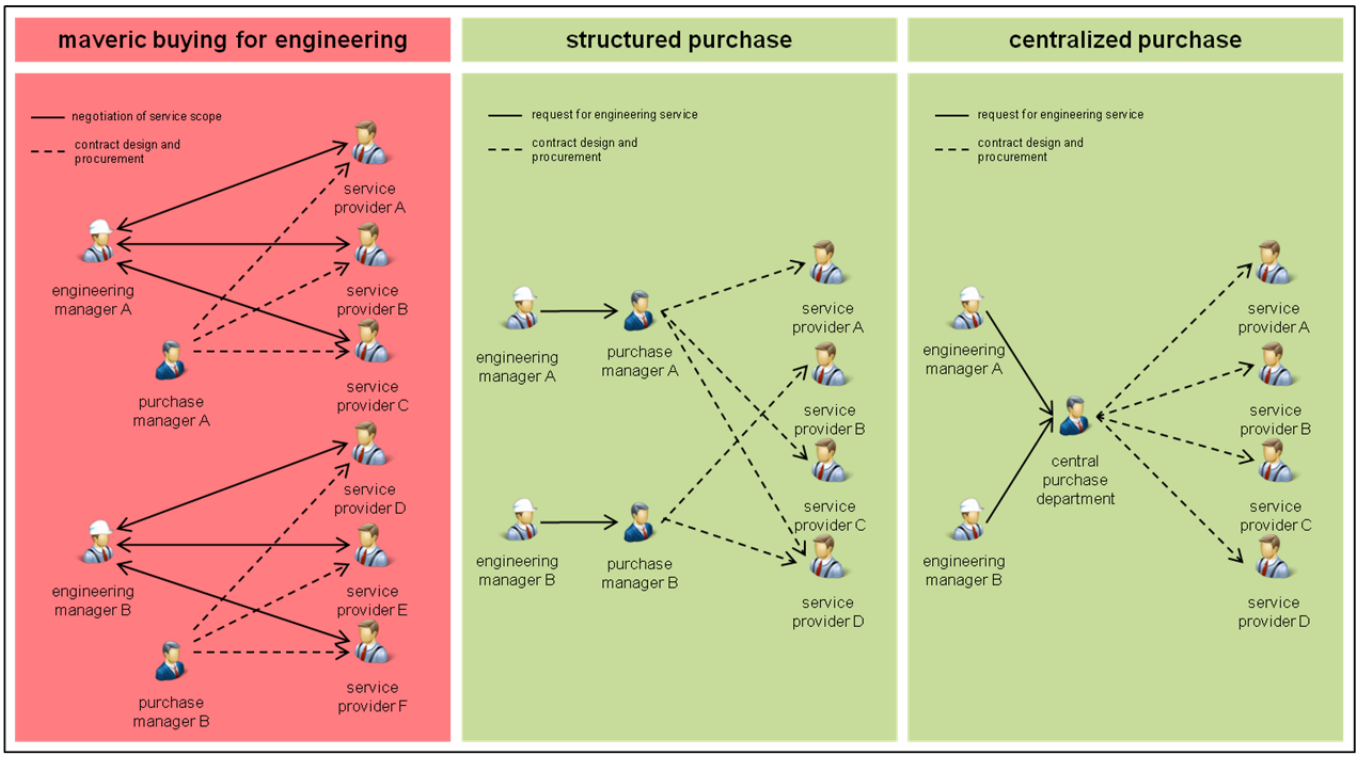

Figure 5: Maverick buying for engineering services

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