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Interdependency in Coordinating Networked Maintenance and Modification Operations

Purpose: The purpose of this research is to detect, through applying a process-based view, how to manage economisation of the maintenance and modification operations in offshore petroleum logistics operations.

Design/methodology/approach: A single case study of engineering services, more specifically, maintenance and modification service operations, on a Norwegian Sea oil platform reveals the dynamics of building network capabilities in a consistent network structure. Two layers of coordination are studied: the engineering process and its context, represented by its network of interconnected firms. This case study empirically grounds how engineering service involves managing reciprocally interdependent exchange processes in the network structure.

Findings: Pooled interdependencies are vital in understanding the nature of service provision and use, and sequential interdependencies are vital in narrating the timing of processes to reveal the nature of process emergence to coordinate strings of production events. Furthermore, the network structure, when characterised by multiple interdependent projects, is also dynamic but at a slower pace.

Originality/value: Through the case study, operations management is revealed to be associated with project emergence at two levels: the core process level regarding daily continuous change, including the changing interaction of multiple different and interdependent projects, and the contextual level, where features of interdependency and integration change, affecting engineering service production. This provides guidance as to the economisation of engineering services. They change not only interactions in the flow of production but also its context.

Keywords: Engineering management; coordination; integration; interdependencies; modification and maintenance operations; process-focused view.

1. Introduction

The purpose of this research is to detect, through applying a process-based view, how to manage economisation of the maintenance and modification operations (MMOs), an ideographic form of research. In this research, MMOs are studied as outsourced engineering services in the Norwegian petroleum industry. This means that engineering competence is a resource purchased by the petroleum producer. This implies a focus on studying engineering services as networked interactions in a focal business relationship.

Previous studies have revealed the complex character of engineering services, including how these services are managed (Engelseth and Zhang, 2012, Engelseth and Pettersen, 2016, Zhang et al., 2016). Rooted in their work on engineering management systems, Zhang and Gregory (2011) and Zhang et al. (2016) point out that there is limited conceptual development regarding engineering services and their globalised network character. Furthermore, operations management (OM) literature, which is often rooted in deterministic time studies, invites considerations of alternative research approaches that are more sensitive to the increasingly dynamic character of industry, focusing on production as emergent temporal processual flows in space (Langley et al., 2013).

Disabling deterministic functionality is therefore a prime motivation of this study. Operations in the service sector are considered, following Bizzi and Langley (2012), as emergent phenomena. Orlikowski and Yates (2002) conceptualise time and timing processes in a comparable manner as a mixture of objective and subjective meanings. Applying this chosen research approach enables this case study to focus on the complexities of supplying engineering services, a *process-focused view* of engineering services provision. Another theoretical issue pertinent to the chosen empirical realm of this study is the finite nature of service packages supplied by the engineering firm; they have a project organisational form. The supply of engineering services is often constituted of a main project comprising several sub-projects that are organisationally timed in relation to each other. This implies first a level of organisation involving the coordination of several different subprojects through administrative processes. Within these projects, production processes are coordinated. This study aims to describe these levels of coordination as a foundation of analysis.

Taking a process-focused view directs research focus to the micro-layer of coordination of these MMOs, the activities of which these operations consist, with increased sensitivity to how they unfold over time (Pettigrew, 1997, Van de Ven, 1992). Plans are thus one of many factors influencing operations. They are one informational artefact of many, a network resource. At this micro-level, resource development, pooling, and use are enacted and adjusted. This focus on ongoing process emergence indicates that a key feature of resources in facilitating production is their degree of flexibility. Due to the fall in oil prices, the Norwegian petroleum industry must economise its offshore operations. Accordingly, this study elaborates on the role of engineering management (EM) (e.g. Zhang and Gregory, 2011; Engelseth and Zhang, 2012, Zhang et al., 2016) as a networked project organisation in the studied MMO case and what constitutes integration and interaction within and between these projects in the studied case.

Supply involves integrative, customer-oriented entities (Vickery et al., 1999). Interactions in this context of change imply uncertainty and demand the use of flexible resources. Kreye (2019) opposes the general view that complexity increases uncertainty. Through a four-case study she indicates that uncertainty in engineering services may to some degree be associated with environmental and technological uncertainty, the context. In these cases, interactions primarily create the uncertainty. It is clearly an emergent phenomenon, generated through interaction, rather than dictated by process context. Furthermore, management of projects can thus be described as proactive or reactive (Yu et al., p. 194). We propose that engineering processes are a mix of administrative reaction and proactivity and that there is always an element of planning and an element of local problem solving as challenges emerge. These are examples of relational and organisational uncertainty. The process itself then generates uncertainty. Producing an engineering service involves mixing these modes of management reaction. The proportions, however, will vary. Engineers involved in managing engineering services are assumed to perpetually experience varying degrees of uncertainty associated with perceptions of a more or less controllable network context. This includes the ever-changing features of customer value (Holbrook, 1994).

This indicates that by “network” we mean not an objective reality “out there” but a research focus indicating the realm of investigation. Taking a process-focused view, networks are not systemic structures or chains but seen as sets of connected exchange relationships in a context

(Cook and Emerson, 1978). This means that presuppositions of one binding functionality or network boundaries are omitted when developing the perspective of this research. The case study concerns the project-related networking activities of an oil company customer and an engineering company offering MMOs on an offshore production platform. Petroleum logistics (PL) are operations that secure economic platform production. These operations encompass substantial risk associated with shutdown potentiality. Keeping the platform continuously in production is therefore a core aim of PL; the platform is therefore continuously subject to MMOs. The MMO network is one of several functionalities within the PL network. This research concerns the functionality of producing the engineering services rather than supplying the platform. In the offshore petroleum industry, MMO engineering services are a cornerstone in securing long-term efficient production of oil and gas raw materials from resources found at sea involving the design of production solutions. This includes modifying technical installations to use the most recent technology in their production. This service also involves changing parts and components, an intermittent and likewise emergent project-organised service flow. Emergence is found at two levels: first, within the process found in the project and its operations, and second, in how the network structure ("supply chain"). This latter aspect is negotiated over time, concerning interdependency, why who works with who, including the issue of ("out") sourcing operations. Part of the challenge is that on the platform, MMOs represent a mix of different projects involving variation in technology and accordingly variation in competence. Flexibility therefore involves not only the changing nature of individual resources but also emergence in managing combinations of people and the tools they use. Figure 1 provides an overview of the studied MMO network:

Insert Figure 1 here

Figure 1. The studied MMO network

Figure 1 illustrates how MMOs as production involve networking between the oil company and its engineering company supplier but also networking with this engineering company's many sub-suppliers, creating a fundamental need for network coordination. Furthermore, this network consists of different sub-suppliers and different types of competency in the engineering service

provider, organised into different projects to support various highly divergent MMO needs, usually involving variation in the forms of technology used and the technology mix then applied in engineering service production.

Literature review

The literature review first develops a view of what constitutes engineering services and their development. Since the engineering services studied in this case represent outsourced operations, considering this form of service provision in a network is a cornerstone. The structure of an industrial network can firstly be characterised by levels of integration. In addition, one of the key features of business relationships in these networks is interdependence, which involves reasoning of why companies interact at a managerial level. This is followed by a section on the technicalities of production as value creation through networked exchanges. This part concludes by describing the applied research framework.

Networked engineering services

Engineering involves social processes that develop and use engineering resources. It is global and modern, associated with the mechanisation and gradual automation of industry (e.g. Giddens, 1990), and found in many forms in business, for example as a function within larger companies and as a core type of competence in “engineering firms”. Figure 3 illustrates engineering as sequence of activities, a process demanding coordination described by Zhang et al. (2011) as “the engineering value chain”:

Insert Figure 2 here

Figure 2. The engineering value chain (Zhang and Gregory, 2011).

The initiation phases in the model (Fig. 1), idea generation, design, and development, evoke how engineering is a creative activity. This creativity is embedded in technology and related to processes and artefacts (e.g. products and machines) design. Kodama (2014) points to how change currently involves the conversion of technology services, the increasingly widespread

pooling of different technologies in a modular fashion. This implies the economisation of interaction between different technologies in engineering services production. In our business case, the focus is on petroleum engineering processes. It is important to point out that the "engineering value chain" does not exemplify a chain comparable to a "supply chain", which usually exhibits a multitude of business functions in a focal firm and how these are interlinked with supplier and customer firms (Lambert et al., 1998). The model concerns interaction and relationships along with what is inherently a complex engineering process, a value-creation process timeline.

Engineering may be outsourced to specialised service firms and may thereby impact on network structure and thus impacting on the sourcing of engineering. This study directs focus to how EM may support value creation within engineering projects through intensive interaction rooted in reciprocal interdependencies found in business relationships in a wider network context. This directs attention to interaction both within a firm administering different projects and between firms in cases where engineering services are outsourced. This implies a notion that business relationships are found not only between companies but also within companies. This also undermines the importance of inter-firm boundaries as a principle for organisation within supply chain management, weakening the importance of classifying supply chain integration as either "internal" or "external".

Production context: integration and interdependency

Coordination in a supply chain concerns how production activities as differentiated processes are purposefully interlinked and carried out. This implies a notion of fragmented production flows demanding "integration". Production takes place in a network structure consisting of a multitude of different business relationships. These may be independent, complementary, or adversarial (Gadde et al., 2010). Integration in a network describes the quality of pooling of resources and actors in the network. This is a relatively stable feature of supply network structure. Accordingly, integration concerns how various business relationships that constitute a supply network that connects the different actors and the resources they use are pooled: tightly or more loosely.

As previously mentioned, interdependency encompasses reasoning to exchange in a network. Social relations found in a network fundamentally entail interdependence, which is a measurable expression of power as well as trust between actors (Emerson, 1962; Pfeffer and Salancik, 1978). Fundamentally speaking, in a network, one firm trades with another because there exists some form of complementarity and mutual bonding of value conception between them. We assume, in line with Thompson (1967), that how firms integrate and work together in a network must be adapted to fundamental characteristics of the type of industry within which they function. Integration is a feature of network structure, the strength of relationship ties found in a network. Integration exists for the purpose of better coordination to use resources. This integration reflects features of interdependency; pooling, sequentially, and reciprocity, classified by Thompson (1967) as types of interdependencies. This classification provides a conceptual direction as to how firms may integrate and thereby better coordinate their supply processes in a network setting. According to Thompson (1967, pp. 101–102), "...human action emerges from interaction of (1) the individual, who brings aspirations, standards, and knowledge or beliefs about causation; and (2) the situation, which presents opportunities and constraints". This forms a core assumption of contingency theory, namely that processes are contextually embedded. Interdependencies are accordingly expressions of this social embeddedness, their "contingency" property.

Thompson's (1967) understanding of organisational interdependency is embedded in systems thinking. This is a slight challenge when using interdependencies in a process-philosophy-based approach. In process thinking, supply purpose associated with value perceptions is a binding common functionality of supply. This perception of value is understood as fragmented (with different and possibly conflicting conceptions) and dynamic. For instance, it is explicit in ecosystems thinking that dysfunctionality in systems may arise due to (1) both measurable and unmeasurable uncertainty, (2) epistemological conflicts regarding whose knowledge counts, (3) arguments over facts, (4) values regarding which goals are legitimate, and (5) variation is the sense of urgency regarding decision-making (Funtowicz and Ravetz, 2009). With process emergence as a characteristic of all these five facets, systems can certainly be considered conceptually as rather messy structures when observed in practice.

When reading the first pages of Thompson's (1967) seminal work *Organizations in Action*, it becomes clear that he was sensitive to the role of uncertainty in industrial interaction and therefore also quite aware of the emergent nature of processes. His discussion is, however, limited to the use of closed as well as open systems, and for his purpose, seeking understanding of what determines how and when organisations act, he states "...we will conceive of organizations as open systems, hence indeterminate and faced with uncertainty, but at the same time as subject to criteria of rationality and hence needing determinateness and certainty (Thompson, 1967, p.10). Accordingly, interdependencies are viewed here detached for a common binding systemic perception of functionality. It is understood rather as an expression of event-specific power that over time may be described as patterns of interdependencies. Thompson (1967) classifies three types of interdependencies:

- (1) pooled,
- (2) sequential,
- (3) reciprocal.

Thompson (1967) uses this classification to describe what differentiates types of industries from one another. These are shown in Figure 3 together with types of activities associated with coordination:

Insert Figure 3 here

Fig. 3. Interdependency and coordination of engineering processes

Defining exactly what constitutes "services" supply is challenging. Gadrey (2000, p. 386) states that it is unlikely that one could ever arrive at a definitive and fully acceptable distinction between goods and services. In this study we focus not on what constitutes services as distinct from the supply of goods but rather on how this form of supply may be economised by especially focusing on interdependencies. Regarding the various types of interdependencies, sequential interdependency is prevalent when activities must follow one another and therefore involve a fundamental form of supply logic; this is a focal characteristic of production in manufacturing and is to a lesser degree prevalent in an engineering service project. However,

production may also reveal pooled and reciprocal interdependencies, which form focal characteristics of production in industrial services (Thompson, 1967; Stabell and Fjeldstad, 1998). In cases of pooled interdependencies, firms produce by combining those heterogeneous resources that they possess and can manage. In cases of reciprocal interdependencies, production is dependent on knowledge interaction, which involves information exchange to curb relatively high uncertainty. In industry, all three forms of interdependencies coexist. Through analysis, indicating the dominant interdependency that helps clarify industry nature and thereby provides guidance as how to manage in such networks. Sequential interdependencies and pooling of resources involve a high degree of complementarity that is manifested through combining heterogeneous resources and timing this combining. Reciprocal interdependencies, however, involve a search for complementarity, which must be *co-created*. When the degree of exchange by management and production becomes routine, it is then institutionalised. Finally, interdependencies change over time and can be managed. For instance, management may seek to reduce reciprocal interdependency in a business relationship to economise integration using information technology. This will increase pooled interdependency.

Production: Value creation through exchange

While the preceding section considered the slow-changing structure of the supply network, we proceed to consider what constitutes the dynamics of producing, that is, the technicalities of OM. We especially focus on production as a networked activity. There, “exchange” is rendered a key feature in this view of producing engineering services.

Following Parsons (1960), organisations are endowed with three distinct levels of responsibility: (1) technical, (2) managerial, and (3) institutional. The technical level encompasses the production of goods and services that create market offerings, the foundation of transfers of title. The managerial level involves mediation between technology and the environment. Institutions encompass meaning and production purposes that are observable as organisational behavioural patterns. Exchange interaction to co-create value is accordingly understood as an iterative boundary spanning supply chain activity. Production in services creates, following Penrose (1959), a service valued by a purchasing customer and service user. Penrose (1959 p. 25), moving away from applying the term “factor of production”, which was

commonplace in economics, states that “it is never resources themselves that are the ‘inputs’ of the production process, but only the services that the resources render”. In this interpretation, “service” denotes the deliverable, a combination of goods and services (note the “s” at the end of the word services, indicating a classification of industry) discussed in the servitisation literature (Vandermerwe and Rada, 1988; Chase and Garvin, 1989; Oliva and Kallenberg, 2003; Baines et al., 2009). Functionality in production is associated with generating customer value. Holbrook (1994) describes customer value as “an interactive relativistic preference experience”. It is therefore not static but an outcome of interaction between the customer and their environment. While the marketing literature, of which Holbrook is a part, describes what constitutes customer value and why this is important, the servitisation literature directs attention to producing this value. The approaches are complementary.

Both “production” and “exchange” characterise service industry supply (Hammervoll, 2014). Exchange (management and interaction between managers) supports the production of value. From an exchange perspective, a service process in the marketplace is associated with the aims of achieving customer value. Exchange may, following Thompson's (1967) classification of industrial interdependencies, involve a combination of pooling resources or reciprocal mutual adjustments where in physical distribution, production is mainly sequentially interdependent. As production is an economy measured in relation to resource use efficiency and process outcome, Hammervoll (2014) stresses that exchange is likewise an economy, albeit supporting production as illustrated in Figure 4:

Insert Figure 4 here

Figure 4. An exchange economy supports a production economy.

Exchange concerns activities before, during, and after transactions involved in the immediate context of individual as well as networked business relationships. Prior to transactions, exchange processes mainly in cases of project management are applied to design production, while after the transaction they directly support production implementation and operations as

well as termination. In this setting where interaction is both complicated and complex engineering service production, customer value is also continuously changing.

Research framework

Following Janusz et al. (2018), process development needs to take into consideration: (1) network integration, (2) business relationship interdependencies, and (3) how people interact in the production process. Engineering, being modern knowledge, is globally dispersed and, as knowledge, easily pooled within the scope of a global economy (Zhang and Engelseth, 2012). Through a large multiple case study of six global engineering service (GES) networks, Zhang et al. (2016) indicate, based on a literature review within OM, three realms of network capabilities of globalised engineering service firms: (1) network resources, (2) network coordination, and (3) network learning. In this study, the aspect of network *coordination* is focused upon since this is associated with how resources (people, goods, tools, and facilities) interact. This interaction is associated with both production processes and the exchange processes supporting production.

Following Mello et al. (2015), engineered-to-order supply, which is typical of the studied MMOs, involves, following Thompson (1967), high degrees of reciprocal interdependency demanding the use of intensive technology to mutually adapt production through exchange. From a network perspective, economising concerns the development of efficient resource use through designing, combining, and utilising resources in activities that interlink different actors (Awaleh et al., 2006). The two other criteria used for describing GES network capabilities, (1) network resources and (2) network learning, are considered in this study as contextual to network coordination. We therefore suggest a conceptual model that shows this intertwined nature of resources, learning, and coordination, where coordination of engineering services is associated with operations that are impacted upon by the development and pooling of physical resources and learning associated with knowledge resources. This is illustrated in Figure 5:

Insert Figure 5 here

Figure 5. Engineering service coordination embedded in resource use

Taking a process-focused view directs the focus to operations. These are associated with exchange in two layers: long-term development and short-term operations. Operations unfold over time (Pettigrew, 1997; Van de Ven, 1992); in this picture, they are complex at two levels: a long-term planning-oriented level and a short-term operations level. From this point of view, plans are rendered one of many factors influencing operations, one informational artefact of many, a network resource. At the operational level, resource development, pooling, and use are enacted and adjusted. This is a product of exchange processes, underpinning the importance of networking. Production process emergence indicates that a key feature of resources in facilitating production is their degree of flexibility, either proactive or reactive. Interaction takes place in the context of a network structure characterised by its degree of integration in the various networked business relationship. Interdependency explains how and why business relationships integrate. How and why do the actors need each other? Interdependencies and integration help describe the network structure, the context of production as flows. This structure impacts both knowledge to manage and operate (using combinations of resources. Both management and operations are regarded as interactions at a daily level within a project. How these different projects are interconnected impacts also on how operations within projects are carried out. Founded on the classification of interdependency, integration, and interaction as key features of services supply provided by Janusz et al. (2018), this understanding of engineering as emergent in a service-producing network is conceptualised. This is shown in Figure 6:

Insert Figure 6 here

Figure 6. Interdependency, integration, and interaction in a service network.

Economisation of production is thus understood at two levels: how operations take place at a daily level and how resources support operations at a contextual level. Economisation of engineering services thus entails considering changing (1) the context of these operations, (2), how this context supports operations, and (3) how operations use resources to produce. In the case of engineering services, this entails predominately informational processes producing technology-based designs that may be used in the studies MMOs. The quality of integration

together with features of interdependency in a business relationships impacts on production. Service production involves interactions. Interaction, however, also takes place in exchange. The process-focused view entails a higher-order conceptual view that implies living with complexity as an alternative to deterministic planning and the control form of management. A process-focused view enhances this perceived complexity, one where interaction, rather than seeking to implement pre-determined activity plans, is highlighted. Reducing uncertainty to economise production, following Kreye (2019), is not simply associated with reducing complexity. Processes themselves generate uncertainty through interaction. Complexity reduction manages environmental and technological uncertainty. Organisational and relational complexity is, however, associated with process development. This provides a nuanced view on developing the reciprocal interdependencies typical of engineering services. Resource development should then be focused on supporting actors in navigating through processes and in their network context. The suggested framework provides a model for what constitutes this complexity and suggests how to manage this complexity at both long-term and operational levels to economise the production of engineering services.

3. Method

Data were collected in line with the approach of Sterns et al. (1998), adapted to PL, a phenomenological approach implying successive use of theory and fieldwork to develop a conceptual framework. The preceding framework emerged through the research process. The following case description is based on an ongoing single case study of firms in a coastal town in Norway that are networked in carrying out offshore-related PL activities. Changes in business relationship configurations at the network level are followed using a “timeline”, in line with the research design by Abrahamsen, Henneberg, and Naudé (2012), also providing insight into the sequential dependencies of operations. Informants were asked to describe their functional roles in the PL network as they saw them, to describe what was perceived as their company’s network role when taking into consideration their description of companies with which they do business, and thereby to more precisely elaborate on their responsibility within that network role. They also included in these descriptions of roles as customers, what they perceived as value formulated as “quality supply”. Based on this network description, the informants then described production processes involved in offshore-related logistics operations. This provided an understanding of how the production of goods and services produced valued outputs, the

objective of exchange. Then the informants proceeded to describe the exchange processes in which they were involved. This type of process description was initiated in the interview by describing how “contracting” was carried out as a process. Through the interviews, contracting emerged as complex and included several layers of purchasing. Therefore the same overall exchange process involved different actors at different levels of exchange, from long-term contracting to more daily purchases within contracts and occasionally emergencies that had to be dealt with. The studied operations were associated with supplies of engineering services grounded in outsourcing of these activities to specialised firms. Therefore, in this study new understandings of EM developed are empirically founded and generated through the line of enquiry described in the analytical framework.

The main outline of this case narrative is based on seven interviews taken from a perpetual research and development process embedded in a close relationship between a locally based academic institution and the petroleum industry in that region. Table 1 provides a list of informants:

Insert Table 1 here

Table 1. Informants interviewed

This research interrelationship includes a series of administered student works on different PL topics ranging from bachelor to doctoral levels, providing rich and varied empirical insight to verify and refine the provided description. Empirical data are also refined through continuous encounters with industry in a local setting where researchers and business practitioners naturally intermingle, among others at a bi-weekly professional meeting administered by the city council. Furthermore, empirical data are enriched by articles in professional-level journals and local media. Case selection was accordingly based on convenience and embedded in knowledge acquired through many years of interaction between this industry and the academic institution involved in this research. More precisely, research was conducted with informants working with the supply base company logistics and purchasing functions of two oil companies and an informant from each engineering firm.

The following case narrative accordingly provides an “as-is” description of this form of value co-creation. Semi-structured interviews were carried out. Interviews lasted on average one hour.

Interviews were taped and transcribed. A research protocol was created to register choices and the main findings of individual interviews and to provide preliminary analysis. This protocol was also used to design follow-up interviews. Accordingly, the study followed an emergent design where the research issue gradually became more precisely formulated as the research project evolved. These descriptions are based on informants' accounts of the past or of possible futures (Corsaro and Snehota, 2012). To some degree, process descriptions involved historical events related to relatively unique processes or strategic-level accounts of business relationships impacting on value-co-creation processes; point mapping where events taking place within accountable time frames is described. This involves mapping the researcher is acting outside of the process. Following Hallinen et al (2012), this means that good interpretative skills are required from both the informants and the researcher. The time-distance to the studied also may cause epistemological problems (Halinen et al., 2012). The research quality is accordingly dependent not only on the features of the investigation but also on how well the informants recollect what they are describing. This also substantiates perpetual investigation, since thereby researchers also gain increased knowledge of the empirical realm. In addition, this calls for interviews of several informants, as in this case design, to account for the same phenomenon, including descriptions of operations involved in both production and exchange. Credibility is sought through providing a detailed case narrative where the level of interpretation is kept to a minimum, allowing for variation in interpretation. Furthermore, the narrative construct and analysis have been discussed with informants as well as being subjected to peer review. The analysis was based on detailed information provided through taped and transcribed interviews. The case narratives were used to find examples and illustrations of features regarding production, exchange, and interaction between these two types of processes.

This is single case study, and therefore it was necessary to explore the detail the material and elaborate on this rather than count or compare incidents. This involved designing the research process leading to, following Dubois and Gadde (2002) to that observations generated new questions guiding following interviews and created new dimensions to understanding, which then provided a new view of the studied phenomenon. However, we believe that understandings developed through this case study may involve theoretical transferability (Meredith, 1998). The findings of this study are regarded as transferable to similar industrial settings provided that the particularities of the industrial setting of this case study are carefully taken into consideration. This is in line with Eisenhardt's (1989) fundamental view of qualitative research. The analysis

has also been supplemented by empirical evidence and insights provided through three separate student-group term projects involving different topics related to PL carried out by both undergraduate- and graduate-level students in logistics management.

4. The MMO engineering case

MMO engineering is described following a line of timed phases of operations:

Insert Figure 7 here

Figure 7. MMO engineering timeline

Production is preceded by tendering, which is finalised by complex contracting. The production of MMO services is supported by management organising these processes on a daily basis, which is particularly exemplified as plans and schedules.

Tendering phase

Although no longer required, the design of MMOs starts with tendering, which involves sales–purchasing interaction to formulate a long-term contract. Purchasing is publicly announced to secure fair market conditions. This has an impact on transactions with both the engineering firms’ customers and their suppliers. The MMO supplier, the engineering firm, has two separate four-year contracts, with a two-year option to prolong these contracts, with two separate oil companies in the studied township. Previously, a competing firm held one of these contracts. The petroleum-company customer views these replacement parts as vital, since they are the tangible, measurable output of the MMO process. However, from the perspective of the engineering company supplying the MMO, it is the service provision that is most challenging. This represents engineering, design, associated with the MMO. As one respondent in this study stated, this indicates that for the engineering firm, MMO represents, at a strategic level, a fine balance between effective goods and service-process outputs.

Contracting phase

Contracting an MMO arrangement between the engineering firms is a prolonged administrative process lasting approximately one year. First, the oil company must provide documentation of

its needs. This involves a lengthy cross-functional process in which different functions report their MMO needs for the coming period. In the case of the land facility servicing the subsea installations, this also involved a major investment in increasing capacity to handle more gas from a new underwater gas pipeline. Documents are paper-based and organised into binders containing several hundred pages with technical requirements, specifications, and technical drawings. Prior to tendering, communication between the oil company and competing engineering-service suppliers may flow freely. After making the offer, public communication must follow strict rules governing interaction in this transaction process. These documents represent a vital part of the bidding process in negotiations. In the case of changes to the publicised tender, the oil company may invite suppliers to a meeting to inform all market actors of the amendments. The engineering firms then create documents of equal proportion stating how they intend to meet the customer needs, as well as pricing their offering. This offering must be in the hands of the oil company within a stated deadline. Three companies listed in the Achilles (www.achilles.com) database are chosen to compete. These companies are ranked in accordance with a rating system where suppliers are apportioned points in accordance with various weighted factors. The creation of this offering is carried out by the head offices of both the oil companies and the engineering companies. From the perspective of one of these oil companies, these agreements commonly involve MMO contracts for all their related needs within the given contract period. Thus, this contract provides the formal context of MMO operations.

Services production phase

Upon winning the bid, the engineering companies commence MMO-related activities. Importantly, this involves purchasing from a set of suppliers. These companies indicate a number of different engineering specialisations or functions that are involved in their MMOs. Examples of such specialisations are within the fields of electronics, structures, instruments, piping, noise control, and steel. Purchasing involves combinations of service and product supplies. Contracts are negotiated in much the same way as these companies' sales contracts with the oil companies. The main contracts run for varying periods – typically two years, with options for prolonging the contract period. These agreements bind purchasing to this supplier for the contract period. The smaller purchases are contracted individually. This involves the use of the Achilles database and supplier ranking. The Achilles database is a web-based service offering that registers qualified suppliers to the Norwegian petroleum industry. The engineering

companies also carry out quality inspections of their suppliers to verify quality features of different processes. The studied engineering company defines a number of projects within its contract with the oil company. A contract is negotiated with a main supplier for each project, where the value of this main project tender is about 70–80 per cent of the project. Accordingly, this supplier provides a technical package. In addition, there are between 10 and 20 minor suppliers. In all, there may be about 50 projects running simultaneously in each engineering company, with these projects involving different companies, people, and competencies. In principle, all purchasing is handled in the same manner. However, the bidding process may be simplified in the case of minor supplies through standardising requirements.

Managing

Projects involve routine meetings. A different set of meetings takes place at the engineering company office in the studied township every week. These meetings consist of approximately five to eight representatives of the engineering company, two to three representatives of one supplier, and two to three representatives of the oil company. Such meetings are operationally focused and always involve only one supplier. These meetings are usually videoconferences, with the suppliers and oil-company customer being represented through video communication. Each project involves at least a weekly meeting. During periods of intense operations, meetings may be carried out daily. In these meetings, the engineering company runs through a checklist that describes the supplies (products and services), logistics, and current operations affiliated with the project. The plan is sought to be verified and potentially adapted based on communication at the meeting.

Planning and scheduling

The development of operational project plans are a major part of MMOs. The engineering company is a global operator and engineers in low-cost countries such as India carry out some of the planning activities. Operations themselves involve using on-site combinations of engineers and skilled workers. Operations take place on the platform. The engineering firm has a dedicated facility at the offshore petroleum supply base in the township, with one person handling goods in transit for MMOs on the platform. On a roughly scheduled basis of one to two ships per week, specialised platform supply vessels transport goods to the platforms. Personnel are transported by helicopter to the platform. On the platform, the main bottleneck is

sleeping capacity. Finally, MMOs involving shutdown of oil production must be carefully timed, since shutdowns are extremely costly. Termination of projects does not always fall in line with plans. In some cases, oil companies decide to change priorities between projects, keeping one project on hold while advancing another. In addition, various factors may create delays, demanding operational coordination through the described project meetings. All the interviewed actors described their business as relatively unpredictable. This includes daily operations. The oil-company customer stated that, viewed from a long-term perspective, logistics solutions in this industry require the development of modes of inter-organisational networking rather than optimisation of micro-level operations.

4. Discussion

MMOs are just one of many forms of many operations found on oil platforms, and any pause in production or failure in operations may have immense economic and environmental consequences. An oil platform is a network in itself, a conglomerate of services supporting relationship-, technology-, and nature-contingent production. MMOs have no long-term detailed masterplan due to constraints found on the platform. Although projects are planned, the empirical findings show how MMOs are characterised by process emergence; they are embedded in complex systems as an empirical phenomenon.

The existent management philosophy is deterministic, and uncertainty is encountered as a challenge with which people have to cope every day through interaction. Interdependency is predominately reciprocal because of the high degree of uncertainty associated with coordination within individual sub-projects and coordination between different sub-projects. A main reason for this way of managing MMOs is related to the high perceived risk associated with these types of operations. The relatively well integrated support infrastructure, involving the use of the routinely pooled resources, is already well developed to support communication, enabling network members to work together in areas including information systems, tools, resources, cultures, and behaviours to coordinate production. These meetings follow quite strictly governed procedures with limited flexibility in operating this exchange process. There is a fear that not abiding to these rules will create severe production discrepancies. Hence, interactions are also highly formalised in a well-integrated context following this learned form of management philosophy, which we characterise as deterministic, following a traditional plan through a control paradigm in neatly formalised steps. These rules, however, only provide a

structure for interaction. What goes on in these meetings has not been studied but is evidently process-emergent. These are events where the outcome is intentionally not predetermined. These meetings function as a problem-solvers. There is no indication of strategic planning to improve the current situation of preventing and putting out fires.

The deterministic picture is empirically real as a mindset embedded in an organisational culture, the discourse, but this discourse is also a management model that is not strictly followed in the case. This is an example of what Parsons (1960) terms “institutionalised behaviour”. This is typical of management activities, the exchange processes. An interesting feature is that *people* were explicitly mentioned by informants in the case study as a core resource. A procurement manager in one of the engineering companies stated that he knew every one of the over 100 employees by their first name. Over time and through project meetings, participants had got to know each other, easing information exchange. Nevertheless, even though trust is evidently high in the studied engineering service network, formalisation of meetings is also high. One may think this is a paradox. This is because the use of checklists to secure quality through exchange processes mitigates risk. In addition, formalised tendering of contracts is demanded by regulations.

Some degree of formalisation is a requirement when applying deterministic planning tools. This is because the plan is clearly based on contracted agreement in this case. What is revealed, however, is a high degree of emergence. The deterministic rules governing interaction are contextual, a part of the institutionalised management behaviour. The interplay between formalised demands and the actual complex engineering process is therefore complementary rather than paradoxical. These engineering services are activities that on one side can be reflected upon as bound by the formalised regulations that create a shell of constraints and at the same time they define the borderlines of potential processes. The formal rules are together not a straightjacket but rather may be interpreted as a definition of context features.

Engineering services, simply stated, imply the use of engineers as a core resource, pooled with tools, facilities, processes, and other people. Embedded in uncertainty, interdependency is predominately reciprocal. Interaction involves the use of “intensive technology” (Thompson, 1967) for mutual adjustment. Pooling supports the finding of engineering services solutions. As human actors, engineers are resources based on specific skills and knowledge. This is expressed

in the case as engineers used as labour in the production economy and as managers in the exchange economy. "Engineers" as labour and as managers implies a form of self-reflexivity as a person; these are two different roles that the engineer must attain through their work by both managing and producing. This self-interaction implies potential for learning, implies reflexivity. This invites changes in perceptions of production. A manager's relationship with the production is not a direct cause-and-effect relationship. In addition, individual engineers' perceptions of production undergo change by being in the collective of the described teamwork. Interaction in the network, the exchange activities, changes how production of engineering services are perceived. This change does not necessarily merge perceptions, creating consensus. Change through interaction can also increase fragmentation and thus also potentially conflict. The aim of engineering management in a network is, still, to integrate. In this MMO case, coordination is accordingly, as described by Zhang et al. (2016), a coordination of both management and production as separate interfacing processes. In the case, very little description of coordination in production is given. Accordingly, it is the exchange economy that is coordinated when seeking to produce quality engineering services. This heightened importance may be interpreted as a feature of this form of technically advanced and mutually embedded service provision.

The role of the "engineering" resource in MMO network management is a core feature of this studied industrial realm. The case data do not account in detail for features of different engineering skills and knowledge associated with the various engineers but would be a viable path for further enquiry to analyse the efficiency of these types of engineering processes. This implies searching for heterogeneity and complementary skills between different types of engineers; that is: how does their knowledge vary in aligning competencies with each other? Furthermore, there is a question of developed trust and the creation of a network atmosphere supporting coordination. This indicates a form of pooled resource interdependency associated with coordinating engineering services since different specialised forms of engineering knowledge in complex services will not provide sufficient guidance to engineer a complete solution for MMOs.

This pooling does not work automatically but needs to be supported by its developed network discourse, institutionalised behaviour (Parsons, 1960). This means that in cases of complex problem solving, engineering usually involves a high level of pooled interdependency

characterising resource use. This also implies that engineers' locations and interconnectivity are vital issues in organising engineering services. In addition, this pooling effort includes a vast range of other inanimate resources such as tools and facilities including the use of information systems. In addition, the engineers must perceive how to work together and feel that this takes place in a good atmosphere characterised by relationship quality. Accordingly, the contextual picture provides a backdrop for process improvement. Once a picture of how to pool engineering knowledge as moving people around is developed in the conceptual modelling of a network, the next step must be to investigate how to integrate these resources and thereby how they may communicate. In cases of detected reciprocal interdependencies, who needs to know what in order to coordinate production is revealed. In addition, modelling would depict a network of actors and the resources they use. In cases of reciprocal interdependencies, coordination is highly dependent on the quality of the mutual adjustment process.

How then can "engineering" as networked services be developed based on the applied process view? In engineering, when outsourced to a service-providing firm, a particular industry-specific form of relationship emerges between these three different types of interdependencies. Sequential interdependencies are technically fundamental since all activity follows a timeline of some sort. Accounting for such interdependencies definitely helps at the basic stage of mapping a process. Operations follow a timeline, and timing engineering services is a core part of designing and operating engineering services. The timeline is associated with designing the engineering process, creating plans, scheduling including deadlines, and coordinating this service with other operations on the platform. Since engineering services are associated with uncertainty and demand event-specific configurations of resources, resource pooling is indispensable as an economic way to organise engineering service production. At a fundamental level, management of engineering services is associated with pooling people, goods, equipment, tools, and facilities. When pooling mediating technology, there is a search for standardisation and facilitate smooth resource interlinking. This inherently dynamic interlinking of resources facilitates, to the degree it is needed, mutual adjustment using intense technology. As Thompson (1967) notes, the use of intense technology for mutual adjustment is a costly way to coordinate operations. Organisations should plan strategically to enhance their mediating technology in order to increasingly automate interactions. Accordingly, achieving increased pooling in MMOs involves seeking to standardise different human and physical resources so that they are technically easy to couple with each other. This implies an aspect of the "exchange economy"

(Hammervoll, 2014) associated with pooling of not only human managerial resources but also technical production resources. Accordingly, it is proposed that exchange is two-fold, involving pooling of management-related knowledge resources and production-related technical resources. These types of pooling can be studied independently of each other and in unison.

This study considers how coordination of engineering services takes place in the network structure of interaction, its interdependencies, and how processes are affected by these interdependencies. This approach evokes a perception that coordination of engineering services is inherently an emergent phenomenon in this type of industry. Commonality, novelty, and adaptability are features of coordination derived from the study by Zhang et al. (2016). These are weakly developed as a unison conceptual model. These features, considered conceptually, may still contribute at this early stage of enquiry to describe the quality of coordination. They then play the role of divergent conceptions of such services. Discerning between an exchange and a production economy and likewise taking into consideration features of interdependence, integration and interaction in the value-producing supply network can help us understand the emergence of these different user conceptions of what characterises engineering service quality. This emergence is related to change at a slow pace in interdependencies and integration and at a continuous level in the operations that characterise production and exchange processes. Our approach sheds conceptual light on these empirical features of service capabilities associated with coordination in networks. Economisation of engineering services is therefore understood as taking place at two levels: (1) in relation to interaction related to the production of engineering services as operations and (2) in relation to more long-term economisation of engineering services by changing the context of these service operations. This context can be changed through altering integration and interdependency attributes.

5. Concluding remarks

When engineering competence is outsourced, this fundamentally changes the nature of engineering operations. From being an in-house horizontally integrated business function, it becomes a purchased service demanding inter-firm service-flow coordination to economise production. This empirical picture is the starting point of this investigation conceptualising features of economisation of engineering services as networked operations.

Accordingly, economising MMOs involves considering change from both a long-term and a short-term perspective. Changing the context of engineering services will indirectly change the service production. This involves changes in roles and the use of tendering, the importance of contracting, and the role of planning. Changing MMOs to a more complex systems form of operations involves more than changing human mindsets. The structures of the network need to be changed. This involves changing interdependency and integration. Interdependency involves how different actors perceive the usefulness of other actors. Importantly, integration involves building trust and increasing technical fitness. Changes here will firstly improve managerial exchange processes to then better support an interorganisational flow of engineering services to carry out MMOs.

In line with Thompson (1967) and Stabell and Fjeldstad (1996), service organisations in general, when developing their service offerings, need to focus on reciprocal and pooled interdependencies. This form of interdependency is inherently complex. Although in research the process view focuses on operations and how they are coordinated, this coordination is dependent on resource investment in its structure, the organisational context, to cope with the challenges of networking in relationships, keeping up with technology, and working in an unpredictable natural environment. This investment encompasses capacity in the form of both (1) knowledge as labour and (2) management and as investments in production resources.

This research reveals that while the engineering processes are clearly complex, so is their network context. The only difference is that the structure changes as projects come and go. In cases of managing multiple projects, as in the case of this MMO project contracted for a minimum of four years, this multiplicity of projects entails dynamics at both the process level and the network level. Furthermore, the network and processes consist of pooling between companies. In the scope of the overall project, the importance of inter-firm borderlines should at least be normatively toned down to secure the necessary integration. Further research will involve detailed modelling of the coordination of engineering service operations to detect the economic considerations of an improved timed connectivity and investments coupled with the use of flexible resources. A similar approach may also be used to study the coordination of services in different production settings and the mixing of service and goods elements in supply offerings, viewed as servitised production configurations.

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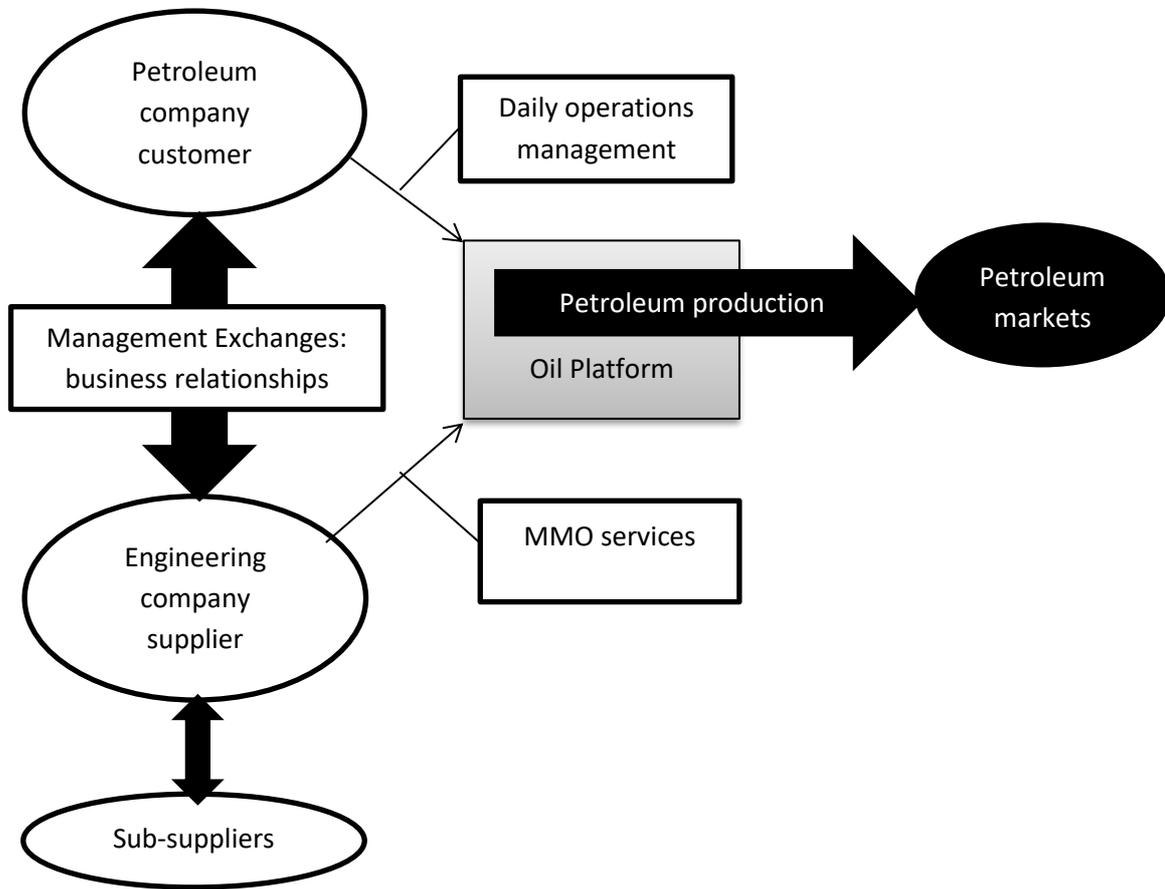


Fig. 1



Figure 2

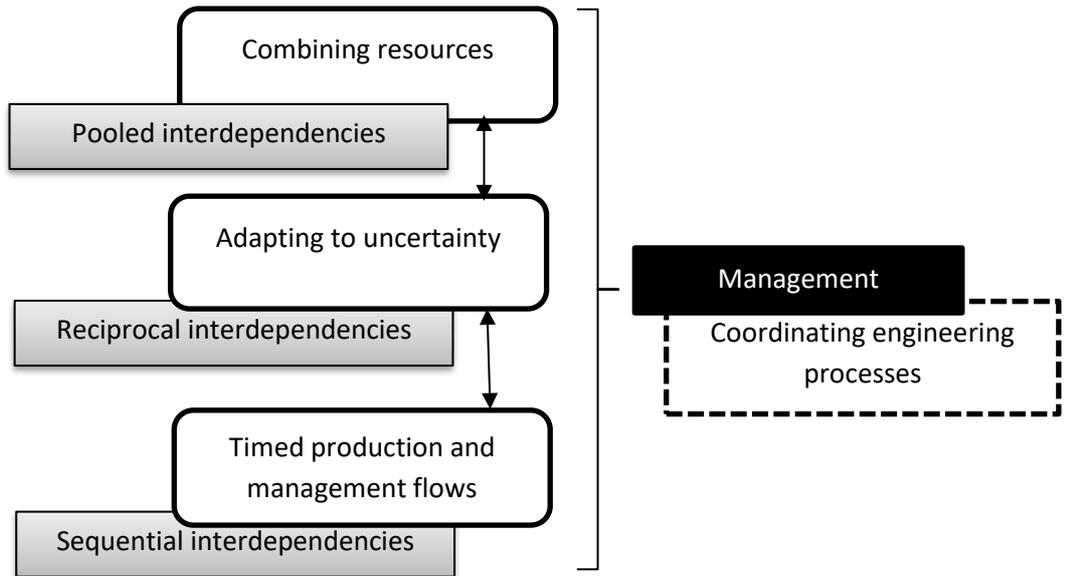


Figure 3

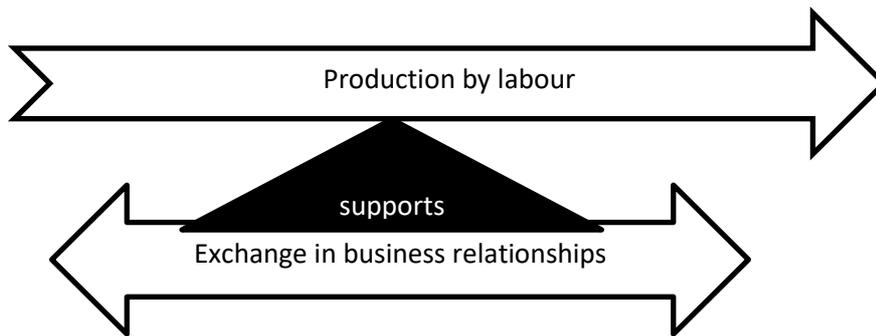


Figure 4

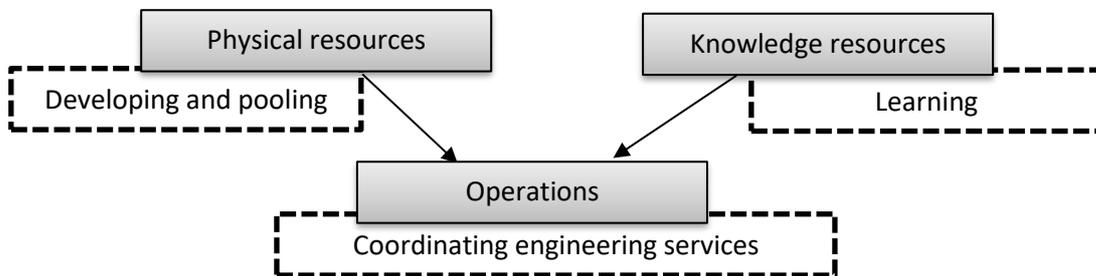


Figure 5

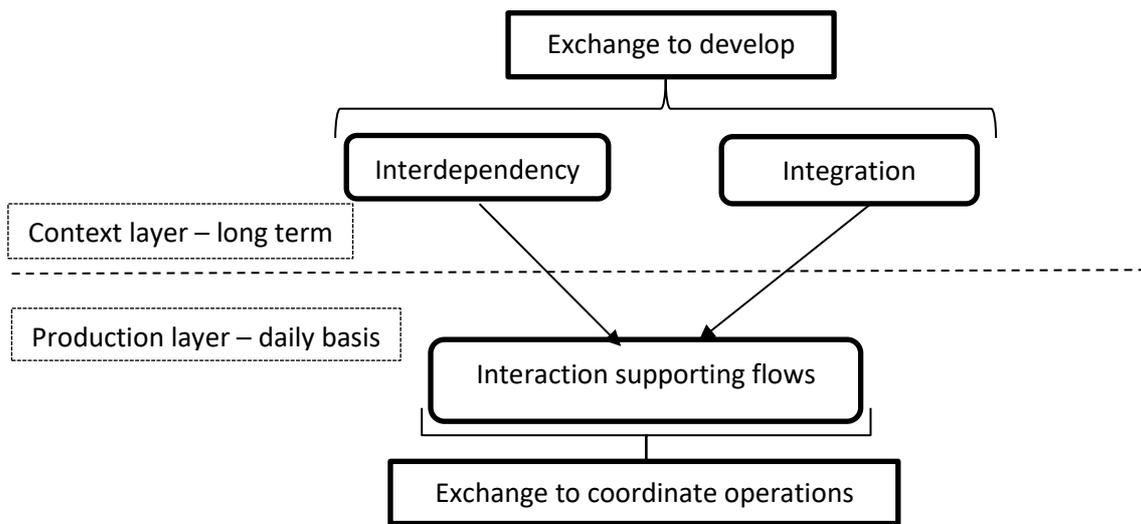


Figure 6

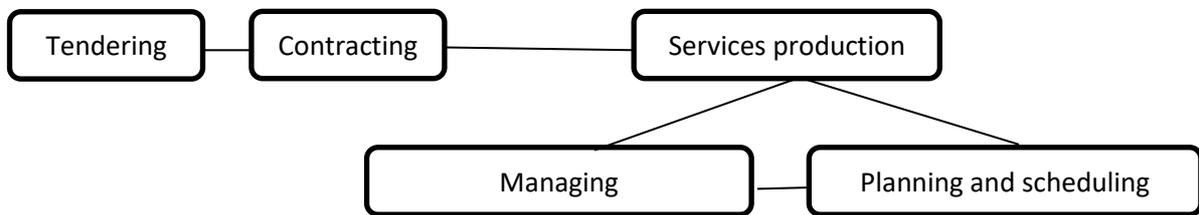


Figure 7

| Informant role | Company | Purpose |
|--------------------|------------------------|--------------------------------------|
| Logistics manager | Supply base | Create overview of the network |
| Logistics manager | MMO provider | Describe MMO processes |
| Project manager | Competing MMO provider | Describe MMO processes |
| Purchasing manager | Oil company 1 | Describe MMO processes |
| Logistics manager | Oil company 2 | Describe MMO processes |
| Logistics manager | MMO provider | Auditing the findings and finalizing |

Table 1