NEED NETWORK ANALYSIS: A PROCESS TO UNDERSTAND THE STAKEHOLDER NEED STRUCTURE IN MULTI-ACTOR SERVICE SYSTEMS

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Abstract

The network analysis and the need matrix can be used together to investigate the relationships of different stakeholders formed by the needs they have towards one another in a multi-actor system. We argue that they serve the goal more effectively when they are used together than alone because: (1) the network analysis allows for a quantitative analysis of the relationships while the need matrix analyses them qualitatively, (2) the network analysis provides a means to visualise the need matrix, (3) these tools supplement each other in approaching complex problems (complex because the diverse stakeholder needs are often interwoven) in the system. We demonstrate the effectiveness of the tools from an empirical study to design new service systems for the energy service companies (ESCO) in South Korea.

Keywords: Social network analysis, Service design, Product-Service Systems (PSS), Sustainability, Design methodology

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1 INTRODUCTION

Design problems in a multi-actor service system manifest as complex entanglements of diverse stakeholder needs. Problem solving may then be compared to observing and untangling the knots in the mesh of needs. For this reason, experts in product-service systems (PSS) development have suggested the investigation of the needs and requirements in a system as a prerequisite to develop solutions that address multiple complex issues. This task is typically done during the planning, exploration, or analysis phase. For instance, Brezet et al. (2001) include a step to analyse an existing system during the exploration stage of the PSS design process. Similarly, business context such as the market, competitors, legislation, and infrastructure is analysed during the analysis phase of service innovation processes (Tukker and Van Halen, 2008; Meier, 2013). According to the Methodology for PSS (Van Halen et al., 2005), stakeholders are identified and their needs analysed during the strategic analysis phase in order to explore design opportunities. Others have emphasised a holistic approach to need investigation. For example, Lindahl et al. (2007) argue that designers need to define the needs and requirements of all stakeholders in the system in order to generate solution concepts that address multiple issues. Burger et al. (2011) also suggest to record and compare the requirement a company and the market from various stakeholders' views. Understanding stakeholder needs holistically is also important from the sustainability point of view. A system that takes into account the interest of all participating actors is likely to be more equitable and resilient than one that favours only a few (Evans et al., 2017).

However, we also found that there is a lack of tools and methods that support a systemic analysis of stakeholder needs. This may be partly because collecting the needs of various stakeholders typically involves a large amount of data and analysing them is time-consuming while the benefit is not obvious. It also increases the complexity and difficulty of design problems as designers have more things to consider and resolve. We thus argue that designers can analyse stakeholder needs better and utilise the results more effectively with relevant tools that support the management and interpretation of the collected data.

This paper introduces a preliminary result of a research that investigates how to understand and design for stakeholder needs in complex systems. It proposes need network analysis, a process of investigating the need structures though the use of need mapping and network theory. In this process, two existing tools - need matrix and social network analysis – are used. In constructing the process, we aimed to address the following questions: (1) How do we identify the stakeholder relationships in a service system formed as the result of exchanges in needs (hereafter described as the need network)? (2) Which characteristics of the need network are associated with untangling the knots? The effectiveness of the process is demonstrated in an empirical study to analyse the energy service companies (ESCO) industry in South Korea.

This paper is structured in the following order: Section 2 describes the context of study with an introduction to the history of Korean ESCO industry and the factors that have limited its sustainable growth. Section 3 introduces the methodology to collect and analyse the data on the stakeholder needs in the ESCO business. Section 4 reports the findings of the stakeholder need analysis and discusses their implications to the design of new service models that address those needs. In section 5, the paper concludes with a summary and suggestions for future work.

2 CONTEXT OF STUDY

Energy saving company (ESCO) is defined as "a business that develops, installs, and arranges financing for projects designed to improve the energy efficiency and maintenance costs for facilities" over a certain period of time (National Association of Energy Service Companies [NAESCO], 2013). ESCO offers products and services for facilitating the penetration of energy efficiency measures by providing users with incentives to adopt them based on the market principle. These services are bundled into the project's cost and are repaid in instalment from the savings achieved through the project, thereby providing financial incentives to energy users to adopt expensive and yet energy-efficiency measures. In addition, it reduces the risk of investment by guaranteeing the energy saving performance through the measurement and verification of energy saving (M&V). In short, ESCO provides packaged solutions on financing, operating and maintaining the facilities.

Since the introduction of ESCO in 90s, Korean ESCO industry has grown to a 170 million-dollar worth market (Ministry of Knowledge and Economy, 2011), accounting for roughly 1.2% of the global ESCO

market. There are over 220 registered ESCO as of 2014 (Yang, 2016). Their main items include high efficiency lighting, waste heat recovery, heating and cooling systems, process improvement, and combined heat and power (Hansen et al., 2009). The government has been actively involved in leading the growth of ESCO industry as a customer, financier, information provider, and policy maker. While some scholars claim that an active government intervention is necessary to create a market and promote ESCO business in the nascent stage (Painuly et al., 2002), others also report that over-regulation has distorted the market mechanism in this supposedly market-oriented model (Rhee et al., 2000). As a result, the market growth over the past two decades has been attributed to the government intervention. At the same time, the market has failed to attract private investment and grow far beyond the scale of the public one (Ministry of Knowledge Economy [MKE], 2010; Yang, 2016).

Several studies report challenges faced by the Korean ESCO industry. Most of them are domestic sources including the reports from government agencies and research centres. Lee et al. (2003), one of few international references, noted the role of government as a market creator that removes barriers and mobilizes necessary capital[1], and identified the future challenges as (1) creating continuous demands by expanding the market from the public sector to the private sector, (2) building capacity for local ESCOs, and (3) promoting private financing and guaranteed savings. More recently, Hansen et al. (2009) reported that the Korean energy services business has not seen as rapid growth as Europe or North America over the past 2.5 decades despite proactive government interventions through policy and legislation. According to the authors, the factors impeding the growth of the ESCO industry include (1) the lack of external capital from the local banks to fund customer projects, (2) ESCOs' heavy reliance on the internal capital mostly funded by the government, and (3) the overburden of ESCOs to take the customers' credit risk by financing the facility investment as well as to achieve technical performances. As we will see later, most of the aforementioned problems are still pertinent to the industry. Despite the infusion of ESCO to various sectors, the market size has not grown significantly over the past decade. As of 2014, more than 90% of the market is financed by the government loans (Yang, 2016). To mitigate the problem without the risk of discouraging the market, private funds with more attractive conditions and larger scales are needed. Private loans are available from banks and non-monetary institutions but their relatively high interest rates and stringent loan conditions make them underutilized by ESCOs which are accustomed to doing business with low-interest public loans. In addition, local ESCOs – particularly small and medium-sized ones – continue to suffer from the lack of technical competence and have thus failed to gain customer trust (Koh, 2010). This is most evident in measure and verification (M&V) – verification of energy saving through quantitative measurement – that takes place towards the end of the ESCO project. For decades, Korean ESCO industry has followed the shared savings contract model in which ESCOs are not liable for rigorous and systematic M&V to reduce transaction costs (Lee at al., 2003). While such a strategy is attractive at the introduction of the market (Patari and Sinkkonen, 2014), it has contributed to establishing a culture where ESCOs do not guarantee energy saving performance or, in some cases, failed to achieve the goal as promised. The industry remains to be heavily dependent on the public fund for its survival. It is contrasted by the governments' commitment to foster its sustainable growth.

We thus conclude that the Korean ESCO industry suffers chronic problems, and assume that these problems are too complex to be addressed by one or two actors that they have put the whole system in a gridlock: as a system consisting of multiple stakeholders with their own set of needs, ESCO can be described as a complex system that operates as the stakeholders interact to fulfil their diverse and interwoven needs. A comprehensive investigation of stakeholder needs may lead to a better understanding of the system problems.

3 METHODOLOGY

3.1 Data collection

To understand the stakeholder needs perceived during the operation of ESCO business, both primary and secondary data were collected. Firstly, we conducted literature reviews of various resources including news articles, magazines, reports, laws, and academic publications. We collected two survey

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[1] The government has been active in promoting ESCO and thus played a leading role in expanding the market through financial and institutional supports. It has invested total 1.7 billion dollars in ESCO business since 1993 and the number of registered ESCOs has grown from 5 to 227 during this period.

reports on the demands of 175 ESCOs and 334 customers, six interviews with ESCOs, an interview with the government agency called the Korea Energy Management Corporation (KEMCO) which implements the national energy efficiency and conservation policies and programs, an interview with the local government, and three interviews with ESCO experts. While these data provided a comprehensive report of the target industry from a macro perspective, they were limited in terms of diversity and quality. The viewpoints of the government and large ESCOs dominated while those of local ESCOs' were rarely covered. Furthermore, stakeholder needs tended to be discussed at the policy and regulatory levels and information about operational needs was limited. We thus conducted a series of interviews with key stakeholders in order to answer the following question: What specific operational needs do ESCO stakeholders have in implementing their business?

The interviewees were selected among the stakeholders with high and mid priority[2], and 61% of the requests for interviews were accepted. Total 12 organizations were interviewed: two large ESCOs, two small and medium ESCOs, KEMCO, a bank, three local governments, two manufacturers, and Korean Association of ESCO (KAESCO) which is an organisation that promotes the interest of ESCOs (Table 1). A semi-structured questionnaire was devised for each stakeholder, and the interviews lasted from thirty to ninety minutes. They were recorded and transcribed for analysis. The names of the interviewees are not disclosed under confidentiality agreement.

Table 1. ESCO stakeholders analysed: by data source

Data type/source	Subject description (Name)	Code
Primary/semi-structured interviews	Large ESCO in energy-efficient lighting, heating & cooling systems, etc. Large ESCO in waste heat recovery, process improvements, etc. Small ESCO and manufacturer of energy-efficient lighting Small ESCO and manufacturer of energy-efficient lighting Government agency (KEMCO) Bank Local government (Gyeonggi Province) Interest group (KAESCO) Manufacturer of lighting Manufacturer of solar panel	LE01 LE02 SME01 SME02 GOV BA01 LGOV01 IG01 MA01 MA02
Secondary/edited interview articles	Large ESCO (STX Energy) Large ESCO (GS Neotech) Large ESCO (Honeywell) Large ESCO (Hwain) Large ESCO (Energy management technologies) Large ESCO (SKC Lighting) Expert (lawyer) Expert (NGO) Expert (scholar) Government agency (KEMCO) Local government (Seoul Municipality)	LE03 LE04 LE05 LE06 LE07 LE08 EX01 EX02 EX03 GOV LGOV02
Secondary/Survey reports	91 ESCOs in South Korea 84 ESCOs in South Korea 113 customers in Gyeonggi Province 221 customers in Seoul City	E01 E02 C01 C02

The interview questionnaires were divided into four sections: (1) basic information of the stakeholder including its role, value propositions, performance in the market, and competitors/partners, (2) business model (for ESCO, bank, and manufacturer) or policies and regulations (for government agency and local government), (3) specific needs with regards to participating in the system, and (4) diagnosis of the current system in terms of perceived strengths and weaknesses at cultural, political and regulatory, strategic and technical levels. The interview details are described in (Baek, 2014).

3.2 Data analysis

For analysis, each stakeholder's needs were identified in terms of their source and destination: the former is a stakeholder who raises the need and the latter a stakeholder held accountable for the need. While the sources were evident, the destinations were not always so. The uncertain destinations were identified based on collective knowledge of the analysts or categorised as miscellaneous. From the source and destination of a need, we could identify the key stakeholders associated with resolving the need and

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2 The priority was determined according to one's influence over and interest to the system (Eden & Ackermann 1998). The results are described in (Baek, 2014).

reflect the finding in solution development. A tool called the need matrix was devised for this purpose. It originates from the stakeholder motivation matrix developed by Jegou, Manzini and Meroni (2004) in order to understand the stakeholders' motivations of participating in a service system. The need matrix is created as follows: (1) An equal-sided matrix whose x and y-axes consist of the actors in a system is created; (2) needs are mapped on the matrix according to their direction so that a coordinate (X,Y) in the matrix is assigned to a need N_{XY}, a need originating from stakeholder X and directed to stakeholder Y. As a result, all stakeholder needs are organised in a two-dimensional coordinate system of source and destination (Figure 1).
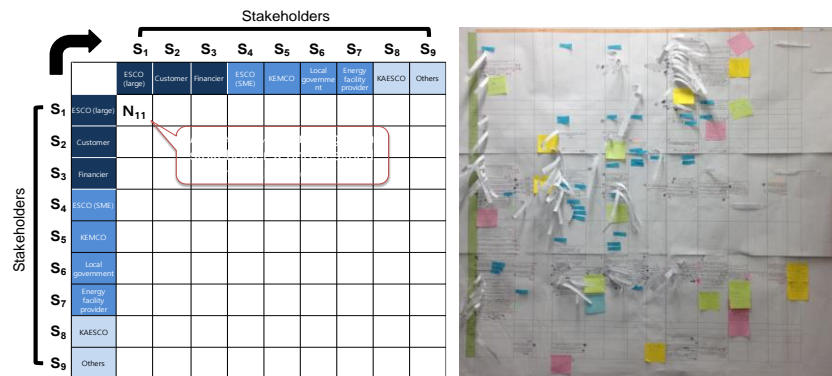

Figure 1. Need matrix template (left) and application (right)

To understand the relationships between the stakeholders in terms of needs, we used social network analysis. Social network analysis is useful to understand the structural attributes of relationships between social entities. It entails defining relevant attributes for investigation, translating the attributes into measurable metrics, collecting and analysing the data, and interpreting the data to understand their implications. The need matrix was designed to coincide with the social network data format (Borgatti et al., 2002) so that the qualitative data from the need matrix can be easily translated into the quantitative data for the need network analysis. During this process, the complete need matrix is quantified and dichotomised. That is, the data in the matrix are first quantified so that each coordinate is assigned with a numerical value identical to the number of needs mapped on the coordinate. Then these numerical values are turned into the data that represent only the absence or presence of needs (e.g. zero or one). As the result, we have a two-dimensional matrix containing zeros and ones that can be readily used for network analysis (Figure 2). Dichotomisation was necessary in this study because the data we have collected did not capture all the needs in the system. Since the data were incomplete, the weight of vertices (the number of needs) were removed. In other words, we did not consider how many needs exist between actors and only considered if there existed any needs between them.
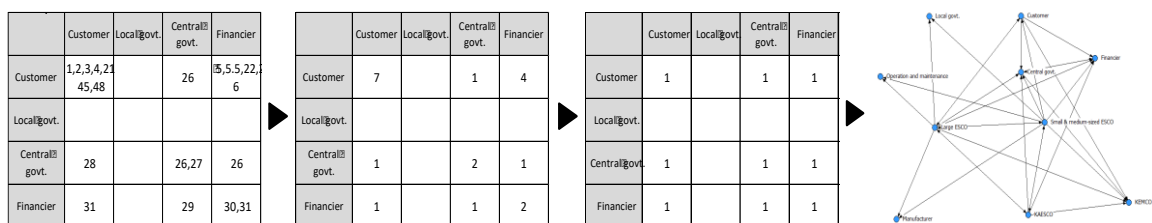

Figure 2. A need matrix with the numeric codes of stakeholder needs, a quantified version, a dichotomised version, a social network (from left to right)

4   RESULTS AND DISCUSSION

From the need matrix, we identified various needs related to the operation of ESCO business, and their sources and destinations.

4.1 Needs from ESCOs to the government

4.1.1 Incentives for energy saving.

ESCOs claim that a major barrier to the growth of ESCO industry is customers' lack of motivation to save energy. Electricity prices in Korea are ranked the lowest among OECD nations for both industry and households, and one of the lower on the list taking account of GDP (IEA, 2012). The government strategy of keeping energy prices low in order to encourage economic growth had a side effect of discouraging proactive investments in energy saving (C01). ESCOs thus complain that building owners, including the public sector, are reluctant to invest in energy efficiency measures (SME01, IG01, E01). Nor are they much knowledgeable in ESCO business and the benefits it brings (C01). Interviewees also mentioned that poor return on investment (ROI) of ESCO and the principal-agent problem in building management, i.e., split incentive between building owners and tenants, also contribute to demotivating energy saving (C01, LGOV02).

4.1.2 Mitigation of risks in doing business.

ESCOs complain that they are overburdened with technical and financial risks in doing business. There are two ways of financing an ESCO project: by user and by service provider, i.e., ESCO. In the former, user finances the project and ESCO guarantees the performance, thereby reducing the uncertainty of ROI. It requires as a prerequisite technological rigor and competence of ESCO. In the latter, ESCO finances the project and does not necessarily guarantee the performance. In Korea, the latter has been strategically promoted by the government as a shortcut to the expansion of ESCO industry. Most ESCO projects are hence financed by service providers (Koh, 2010). This strategy may have contributed to the growth of the industry in size, but not in quality, and the industry is ill reputed for a lack of technical rigor and competitiveness. As a remedy, the government introduced in 2013 a new policy in which ESCOs are asked to finance a project and guarantees the performance. ESCOs are now confronted with an even more challenging situation in which they have to bear both technical and financial risks (LE01, SME01, IG01, LE04, LE07).

4.1.3 Regulation vs deregulation.

There is a conflict of needs between small and medium-sized ESCOs and large ones regarding the allocation of the public fund. As they compete for the fund, the former asks for protection from monopolization by large companies while the latter demands deregulation allowing free competition.

4.2 Needs from ESCOs and banks to the government

4.2.1 Affordable and accessible funds

ESCOs demand for more accessible and affordable financing solutions than the existing public and private funds. They complain that the public fund is much too limited in amount and the private funds too expensive to loan. They thus ask for an expansion of the public fund or procurement of private funds with a lower interest rate and instant access (LE02, LGOV02). Since many ESCOs have liabilities from financing projects, they also need a way of accessing funds with low credit limit (LE02, LGOV02).

4.2.2 Flexible management of the public fund

Another need relates to more efficient and flexible management of the public fund. SME02 points out that the fund tends to be underutilized due to a disproportion between demand and availability. It argues that the allocation of funding should be more responsive to changes in demand. Lastly, there is a conflict of interest between ESCOs and banks. While the ESCOs argue that the governmental support is essential given the high interest rates of the private financing in general[3] (IG01), the bank claims that the low interest rate of public fund discourages the use of private funds (BA01).

4.2.3 Miscellaneous

The needs in others category include: collaboration and partnership between large ESCOs and small and local ones (IG01), simple and client-friendly contract terms (C01), transparency and fairness in

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[3] The base money rate of the Bank of Korea is 2.5%, higher than 0-0.25% of the Federal Reserve System in US, 0.25% of the European Central Bank in Europe.

tendering process (SME01), stabilization of LED prices (SME02), new strategies for the inclusion of small buildings into ESCO business (LGOV01), a safeguard against clients' financial instability (SME02), culture and policies to allow for long-term projects (>3 years) (SME01), a service to conciliate legal disputes (SME02), and finally opportunities to utilise energy-related financial products as a means for corporate social responsibility and marketing (BA01).

4.3 Needs from ESCOs to customers

4.3.1 Fair profit sharing

Principles and rules in profit sharing are often violated by ESCOs and clients (SME01, LE02, IG01). In the shared savings model, one of the financing models in Korean ESCO business[4], an ESCO is asked to take the customer's credit risk and instead share the profit gained by a surplus saving. In reality, however, the profits are often not shared with the ESCO. The ESCO hence has no financial incentive from maximizing energy saving, which results in ineffective ESCO performance. It is speculated that the problem is due to the low bargaining power of ESCOs in a highly competitive and price-sensitive market.

4.3.2 Service-oriented solutions and culture

In general, when customers are not willing to pay for services as much as for products, a service provider has no alternative but to offer product-oriented solutions. This has been the case with Korean ESCO industry, and we argue that product-oriented consumption culture weakens its profitability and technical competence. The strength of ESCOs lies in its ability to achieve energy efficiency and ROI with solutions in the form of a product-service mix. If their value proposition is set on selling products, they lose competitiveness over product manufacturers that also offer product-oriented services with a price advantage (LE01). ESCOs claim that the culture of underestimating service values is a barrier to offering service-oriented solutions. For instance, many customers prefer not to include maintenance in the scope of project as they find it more economical to provide it internally (IG01). Others request for maintenance at unreasonable prices (LE01, SME02), and the ESCOs with a weak bargaining power have to accept the request to maintain a good relationship with them (SME02).

4.4 Needs from customers to ESCOs (and vice versa)

4.4.1 Rigorous and paid M&V.

While both customers and ESCOs agree on the importance of rigorous and accurate M&V, they disagree on who should pay for it. The survey reports that the majority of customers does not trust ESCO (74%) nor are they satisfied with the ROI in energy saving (54%) or cost saving (57%). Customers request ESCO for an accurate diagnosis of energy use before the project and verification of the performance after the project. It also demands specific information of where the saving, if any, comes from (LE01). In other words, customers expect from ESCO a consistent and reliable performance that achieves an aimed ROI. ESCOs also believe that it is crucial to the success of business to build trust with customers through rigorous M&V (LE01, C01). In reality, however, rigorous M&V has been for decades an Achilles' heel for Korean ESCOs. KAESCO argues that the mismatch between supply and demand is due to ESCO's technological incapacity and the absence of local M&V guideline specific to Korean context (IG01). However, interviews with ESCO suggest that there may be another reason which relates to customers' perception of paying for M&V. Customers often consider M&V, and other product-oriented services, as "extra" features that should add little to the cost. This is the manifestation of the product-oriented consumption culture in section 4.3.2. ESCOs respond with cheap and low-quality services (LE01).

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[4] The shared saving model is one of the three financing models in Korean ESCO business. It is no more supported by the government loan since 2013 for the reasons of ineffective energy saving and financial risk imposed on ESCOs. The other two models are the guaranteed saving model in which the ESCO takes the technical risk by providing a guarantee of the energy saving performance of its installation work while freed from the customer credit risk, and the new shared saving model where the ESCO takes both the financial and technical risks.

4.5 Needs from customers, the government, and the interest group to ESCOs

4.5.1 Technological reinforcement of ESCOs

Customers, KEMCO and KAESCO unanimously point out that many ESCOs, especially small and medium-sized, lack technological competence to provide a rigorous and effective solution (C01, GOV, IG01). The survey (Koh, 2010) reports that the majority of customers are not satisfied with the performance of ESCO, and 25% of the customers experience technological and structural problems during ESCO projects. The interest group argues that the overall credence of ESCO suffers from the proliferation of low quality or pseudo ESCOs [5] with cost leadership (IG01). The government acknowledges the problem and tries to control the quality of ESCOs through a more selective process to authorize and support ESCO (GOV). However, this will jeopardise small ESCOs which cannot afford research and development in technologies (SME01).

4.6 Needs within the government

4.6.1 Policy and regulatory support

The need for policy and regulatory support was raised by the government agency administering ESCO business and local governments. The central government is keen on reducing energy costs and CO_2 emission at the national level due to aggravating energy scarcity and increasing environmental pressure (GOV). While the local governments have important roles to play in ESCO as a customer and a facilitator, some of them have been accused of being reluctant to achieve energy efficiency (LGOV02). Fortunately, the situation is changing in favour of ESCO. There is an increasing pressure by the central government upon energy users to respond to energy scarcity and climate change. Provoked by the nationwide energy crises in the recent years, the government is imposing more aggressive regulatory measures such as raising the electricity prices and replacing the lightings in public buildings with LED to influence energy consumption behaviours and create new demands in the energy market. The government has also adopted carbon emission trading in 2015, which can increase the demand for energy efficiency measures.

4.7 Need network

The stakeholder need network illustrates how the stakeholders' unmet needs are distributed across the value network. To identify the congestion in the need flows, we measured the degree centrality of each node. Degree centrality is defined as the number of ties incident upon the actors in a network. Since the need network is directed, i.e. vertices have directions, we have two separate measures of degree centrality – indegree and outdegree. In this study, the nodes with vertices heading inward (indegree) indicate the actors receiving needs from the other actors while those with vertices heading outward (outdegree) are the actors having needs to the others.

The nodes with high indegree are the actors receiving needs from many other actors. Their relationships of needs with other actors render them a bottleneck in decision making. The magnitude of their impact to the system is proportionate to their salience in the system.

In the ESCO industry, the central government, customer, and ESCO have higher indegrees than the rest (Figure 3). The needs oriented to the government are associated with policies, regulations, and conventions that the stakeholders perceive as barriers to innovation and growth of the industry (4.1.1, 4.2.1, 4.2.2, 4.6.1). Those oriented to customer are largely related to culture and conventions, some of which are the consequence of policies and regulations (4.3.1, 4.3.2). The needs oriented to ESCO are concerned with the strategic and technical issues in conducting ESCO projects (4.4.1, 4.5.1). The needs designated to financier are substantial considering its currently passive involvement in the business (4.2.1). This seems to convey its impact on financing the private loans and its potential to drive the growth of the industry.

The nodes with high outdegree indicate the actors having needs towards many other actors. They are likely to be deeply involved in the system operation and have a vested interest in improving the system. The outdegree is particularly higher among ESCOs and customer (Figure 2). ESCOs' needs towards the other stakeholders exist in culture and conventions (4.2.1, 4.2.3, 4.3.2), policies and regulations (4.1.1, 4.2.3), and strategic and technical issues (4.2.3, 4.5.1). Over 80% of the needs are associated with

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[5] A company that offers ESCO solutions without a certificate and therefore at more competitive prices than ESCOs

policies and regulations, implying that ESCOs consider these problems to be mostly external and their role in addressing these problems to be limited.

Customers' needs ranges from cultures and conventions (4.1.1), technical issues (4.2.3, 4.4.1, 4.5.1), and policies and regulations (4.1.1). Looking in depth, the needs related to cultures and conventions are directed to themselves, i.e. they acknowledge their lack of interest in energy saving practices. Strategic and technical issues are directed to ESCOs and landlords, and policy-related needs to the government and financiers. While the government acknowledge the need for additional policy and regulatory support, the proposed measures seem to be local and lack the impact necessary to fix the wicked problems that have existed for over a decade.
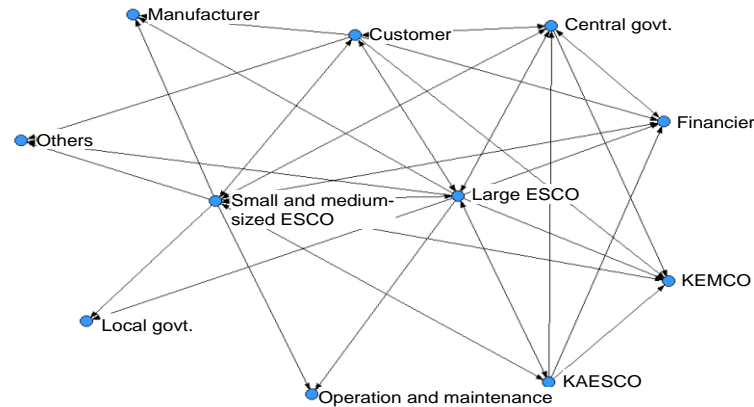

Figure 3. Visualisation of the stakeholder need network in the ESCO system (This diagram does not show the internal needs that the stakeholders have towards themselves.)

We interpret the results as follows. The central government plays a critical role in ESCO business as the most influential decision maker. The other stakeholders see ineffective political and regulatory measures as a major barrier to the innovation of ESCO. ESCOs and customers have their interest strongly vested in ESCO and thus have loud voices in improving the system. Ironically the other stakeholders see them as part of the problem but they do not recognise it as much. This is evidenced by relatively few internal needs, i.e. the needs directed to themselves (13%). On the contrary, the fact that most needs are orientated to others in the system implies that the stakeholders are highly interlinked and interdependent in terms of need fulfilment, and that problem solving will require negotiations and cooperation among them. For example, fulfilling the need for a safeguard against customers' financial instability may require a consensus among an ESCO, customer, an insurance company, and KEMCO on raising the service price in return for a reduced liability of ESCOs.

5 CONCLUSION

This paper introduces tools that support the analysis of stakeholder needs in a multi-actor service system. The proposed tools, namely the need matrix and need network analysis, can be used together to manage and interpret of the data related to the stakeholder needs and requirements, and contribute to a holistic understanding of the needs in the system. The effectiveness of these tools was tested through an empirical study to analyse stakeholder needs in the ESCO industry. The study demonstrates that the tools are useful for identifying various needs related to the operation of ESCO business, and their sources and destinations; and understanding the structural attributes of complex relationships between stakeholders in terms of their needs to one another. We expect that this paper will provide useful tools to designers for understanding a complex structure of vested interests in multi-actor service systems.

Future works include a more sophisticated analysis of the need network including the identification and measurement of additional attributes relevant to the problems in the ESCO system. For instance, the betweenness centrality associated with an actor's influence on communication and the transfer of information (needs in this case) can be measured to identify the stakeholders holding the key to the innovation and sustainable growth of the industry. Another topic of interest is the degree centrality as a measure for stakeholder prioritisation. If the indegree and outdegree in the need network can be associated with the salience and interest of stakeholders respectively, their measurement would allow

one to prioritise stakeholders according to their influence over and interest to the system (Eden & Ackermann 1998).

REFERENCES

A report on the strategies to reinvigorate ESCO industry (2010), Seoul, South Korea: Ministry of Knowledge and Economy.

Baek, J. S.(2014), 'A real-world experience of product-service system development for intelligent LED system', *International Design Conference 2014, Dubrovnik, Croatia: Design Society.*

Borgatti, S., Everett, M. and Freeman, L. (2002), *Ucinet for Windows: Software for Social Network Analysis.* Harvard, MA: Analytic Technologies.

Brezet, J. C., Bijma, A. S., Ehrenfeld, J. and Silvester, S. (2001), The design of eco-efficient services: method, tools and review of the case study based on 'Designing eco-efficient services' project, Design for Sustainability Program: TUDelft.

Burger, T., Ganz, W., Pezzotta, G., Rapaccini, M. and Saccani, N. (2011), 'Service development for product services: a maturity model and a field research', *Productivity of Services NextGen-Beyond Output/Input. RESER.*

Eden, C. and Ackermann, F. (1998), *Making Strategy: The Journey of Strategic Management.* London: Sage Publications.

Evans, S., Fernando, L., & Yang, M. (2017), Sustainable value creation—from concept towards implementation. In R. Stark (Ed.), *Sustainable manufacturing, sustainable production, life cycle engineering and management*: Springer.

Halen, C. v., Vezzoli, C. and Wimmer, R. (2005), *Methodology for Product Service System Innovation.* Assen: Van Gorcum.

Hansen, S. J., Bertoldi, P. and Langlois, P. (2009), *ESCOs Around the World: Lessons Learned in 49 Countries.* Florida: CRC Press.

Heo, J. S. (2013), *Introduction to ESCO business*, Seoul, South Korea: Ministry of Knowledge and Economy, Korea Energy Management Corporation.

Electricity information (2012), Paris, France: International energy Agency.

Jegou, F., Manzini, E. and Meroni, A. (2004), 'Design plan, a toolbox to facilitate solution oriented partnerships', in Jegou, F. & Joore, P. (eds.) *Food delivery solutions: Cases of solutions oriented partnership.* Cranfield: Cranfield University.

Kim, M. H. and Kim, M. K. (2011), *Policy suggestions for invigorating the ESCO industry in Seoul*, Seoul: Seoul Development Institute.

Koh, J. K. (2010), *Promotion of ESCOs in Gyeonggi-Do*, Suwon: Gyeonggi Research Institute.

Lee, M.-K., Park, H., Noh, J. and Painuly, J. P. (2003), 'Promoting energy efficiency financing and ESCOs in developing countries: experiences from Korean ESCO business', *Journal of Cleaner Production,* 11(2003), pp. 651-657.

Lindahl, M., Sundin, E., Sakao, T. and Shimomura, Y. (2007), 'Integrated product and service engineering versus design for environment—a comparison and evaluation of advantages and disadvantages'. *Advances in Life Cycle Engineering for Sustainable Manufacturing Businesses*: Springer, pp. 137-142.

Meier, H. (2013), Product-service integration for sustainable solutions. Berlin: Springer.

NAESCO (2011), *What is an ESCO?* Washington, DC: NAESCO. Available at: http://www.naesco.org/resources/esco.htm 2013

Pätäri, S. and Sinkkonen, K. (2014), 'Energy Service Companies and Energy Performance Contracting: is there a need to renew the business model? Insights from a Delphi study', *Journal of Cleaner Production,* 66(2014), pp. 264-271.

Rhee, C.-H., Lee, K.-D. and Park, J.-J. 'The Activation Strategy of Energy Service Companies (ESCOs) Under Deregulation in Korea', *2000 ACEEE Summer Study on Energy Efficiency in Buildings*, Pacific Grove, CA: American Council for an Energy-Efficient Economy.

Seo, Y.-D. (2016), 'An urgent demand for ESCO experts', *Energy Economy*, February 29, 2016. Available at: http://www.esco.or.kr/notice/pds?bc_seq=8&method=view&b_seq=4854

Tukker, A. and Van Halen, C. (2003), *Innovation scan for product service systems*, London: PriceWaterhouseCoopers.

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