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Procedia CIRP 00 (2018) 000–000

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10th CIRP Conference on Industrial Product-Service Systems, IPS^2 2018, 29-31 May 2018, Linköping, Sweden

Development of the urban and industrial symbiosis in western Mälardalen

Martin Kurdve[ab]*, Christina Jönsson[b], Ann-Sofie Granzell[c]

[a]*Chalmers University of Technology ,dept of Technology Management and Economics, Supply and Operations Management, 412, 96 Göteborg, Sweden*
[b]*Swerea IVF AB, 431 53 Mölndal Sweden*
[c]*Smart Planet Business AB, 723 46 Västerås,*

* Corresponding author. Tel.: +46 31 7721000; fax: +0-000-000-0000. *E-mail address:* martin.kurdve@chalmers.se

Abstract

From a business model development perspective, this paper presents a case study of Västra Mälardalens industrial symbiosis, the current state and potentials for further development. The current status of the regional symbiosis network and potentials based on a survey and workshops together with statistical background data is used to evaluate the potential improvement areas and suggest future research. The study contributes with application of evaluation models and confirm earlier research and in addition suggest future research in the field. The Symbiosis network have potential to be acting as innovation catalyst supporting companies to go beyond core business development.

Peer-review under responsibility of the scientific committee of the 10th CIRP Conference on Industrial Product-Service Systems.

Keywords: Industrial symbiosis; Product service systems; Sustainable industrial development; Regional innovation networks;

1. Introduction

Urban and industrial sustainability in relation to resource efficiency is increasingly demanded and pursued combined with cost efficiency. Since waste of energy and materials contribute to high environmental impacts and high costs, reducing these wastes and/or making secondary use of these wastes is of great sustainability importance [1,2]. Maximizing transport efficiency, using more effective transport modes and using less fossil fuel is also recommended. Fossil free solutions e.g. promoting solar energy and efficient heating/cooling exchange is also regarded important for sustainability.

One way to address resource efficiency is to try to share physical resources locally, and let unneeded outlets from one enterprise feed another enterprise or share resources needed seldom in common pooling systems. Urban and industrial symbiosis (UIS) often referred to as industrial symbiosis is the network of community and industrial actors collaborating to bridge local needs by improved resource utilization [3]. The collaboration may include intangible values and require business models between actors that can handle both products and services. The individual business relations within an UIS may require product service system(PSS) business models to utilize the resources [4].

The West Mälardalen region is a sub-region of Västmanlands län, an administrative body in Sweden. The UIS-network in the region started already in the 1980-ies with a district heating collaboration in Köping municipality where industries could tap in their excess heat. In addition, manufacturing competence centers like Kuggcentrum has been acting in the region as network for industrial competence exchange. Recently the energy network has extended to the three municipalities of the region and a broader exchange of materials, transportations and common competences is developed.

1.1. Aim

The aim of this research is twofold. First, based on the current status, to propose a strategy for local authorities and action researchers to follow in the development of the UIS. Second, to propose a method for further mapping of collaboration between companies in the region focusing on factors important for continued development of the UIS in all

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of the focus areas. The research questions formulated to reach this aim is:

RQ1.a How should an UIS development state be mapped?

RQ1.b How can such evaluation be used for future strategy?

RQ2. What factors are critical for further development and how can the UIS catalyse concrete solutions?

The scientific contribution lies in empirical data on how to map regional UIS systems and development of an UIS.

2. Method

According to Mirata [3] regional industrial history and the nature of the companies involved in an urban and industrial symbiosis (UIS) influences the progress of the program. The importance of municipality involvement and to have some large manufacturing companies in the IUS-network as fore runners is pointed out by some authors [3,1]. Personal and organizational aspects will affect the success of the symbiosis.

Thus, this analysis takes a starting point in collecting open statistical data for the background of industrial development and innovation in the county, its industrial specialization compared to other counties in Sweden and the current status, with regards to UIS, of the companies involved (Regional history and background in Fig. 1). The empirical study included action research, participating in the prestudy 'Industriell symbios i västra Mälardalen', conducting a survey, workshops and an analysis (investigating the nature of involved organisations and maturity of the UIS in fig. 1) with aim to support development of the UIS.

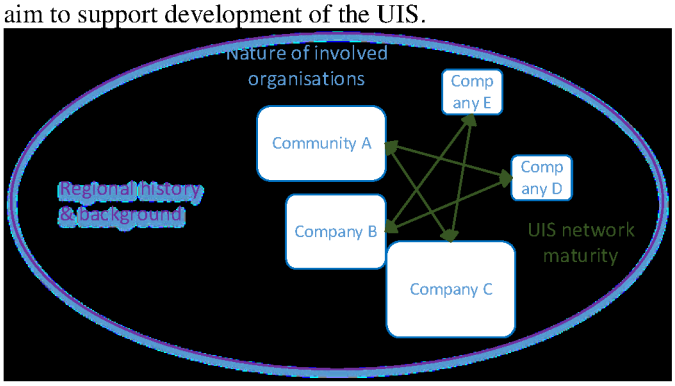

Fig. 1. Elements in the analysis of the current state of the UIS.

The UIS purpose have for this pre-study been to support companies strive to become resource efficient. Therefore, certain focus areas were proposed, namely energy, material transportation, and competence in terms of personnel resources and networks, clusters and for instance academic actors in the region. WS and interviews have discussed these focus areas and aimed at identifying new solutions that can be offered by two or more actors together in common initiatives.

The overall critical factors for the existence of a UIS have been analysed for the appointed local UIS in Västra Mälardalen. The current status of companies' collaboration was investigated by a survey examining the status of collaboration and collaboration interest. The survey questions, inspired by waste flow mapping [5] transportation and energy mapping, asked about current use, current circularity and sharing, and potentials of sharing. 20 companies answered the survey, among them the two largest industrial employers in the region with over 500 local employees each.

The collaboration around different types of physical resources and competence/innovation shared were then analysed separately inspired by Golev et al. [6], maturity model and by identifying possible hinders for UIS. The model evaluates a symbiosis as 1. *Not recognized*, 2. *Initialised*, 3. *Active*, 4. *Proactive* or 5. *Forming the future*. The evaluation was done for energy, material and transportation sharing and to some respect on innovation and knowledge sharing. The sub question/issue level identified were investigated via surveys and interviews, with 20 companies with company representatives in the region. To identify challenges that are hindering UIS-development categories of barriers/enablers were used; Commitment and community awareness, cooperation and information sharing, regulatory requirements, economic and technical feasibility [6]. The evaluation was used as input for further development of the UIS. Two workshops with companies in the region were used to get input about ideas and potentials for the future. In addition, one workshop with project leaders and researchers from several UIS in Sotenäs took place with results that may be seen as a benchmark with other regional UISes.

The data collection and results method are summarised in four steps:

- Regional industrial history, status and specialization
- Regional innovation collaboration
- Maturity evaluation /resource-area
- Innovation development factors

3. Theoretical background

Although several examples of documented resource efficiency benefits of applying product service systems (PSS) and servitizing [7, 8, 9], regular linear business models are still predominant. Since PSS is a complex relation the parties need to have trust and communication, common goals and targets as well as to assure knowledge for the future development of the product/service [9]. Also, sustainability is not automatic in a PSS but must be designed into the business models [10]. An urban and industrial symbiosis network (UIS) is a means for sustainability. It can be used as a common forum to formulate common goals and facilitate trust and communication [4]. It may be important to facilitate common long-term knowledge management and innovation activities within the UIS [11].

Symbiosis in biology means that different species "living together" and may even include relations where only one of the parties' benefit from the relation e.g. parasitism [12]. However, among the different definitions of what an industrial symbiosis or urban and industrial symbiosis is, most authors agree that there should be some sort of mutual benefit, synergies for the parties [3, 6, 13]. Also a UIS has to, according to several definitions, be beneficial for sustainable development by being more resource efficient and /or promote renewable resources. Lombardi and Laybourne [14] mean that industrial symbiosis "engages diverse organizations in a network to foster eco-innovation and long-term culture change".

The business models between parties in an industrial symbiosis need to fit UIS definition and should include

products, services and an aim for sustainable development [1]. Such business models can be classified as product service systems (PSS) [7, 15]. In a collaboration around sharing physical resources the parties (provider, user) collaborating over a resource need to define the physical resource, the service or function adding value to the user, the responsibilities and risks associated before a business model can be agreed (see fig. 1) [9, 16]. Barriers in PSS collaboration has been identified as lack of trust/communication, lack of knowledge, and lack of common goals [4, 9].

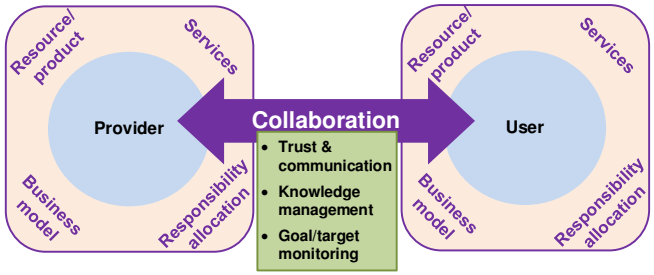

Fig. 1. Collaboration model redrawn from [16].

It is important to acknowledge the full value of the PSS. The provider gains further values than just the payment for the product/service. These provider values may be; enhanced customer relations, strengthened infrastructure, increased quality and environmental performance improved brand etc. [17]. These added values need however to be designed into the business models. To improve business model innovation for the actors, the UIS network can be useful, forming a context for sustainable business innovation activities [11, 14].

The potential synergies of UIS is limited by several nontechnical barriers [6]. These barriers can be; lack of community awareness, cooperation, information over the shared resources or commitment to the common sustainability development goals. They may also include technical, regulatory or economic obstacles. These can be overcome by network innovation activities and knowledge sharing [6, 11].

To enhance innovation and manage knowledge in a regional network setting, research centres should be aiming for win-win or “developed collaboration” between academia and industry. In order to achieve efficient research and development knowledge needs to go both ways, beneficial for both parties [18]. Some critical collaboration attributes for innovation networks are that they are dependent on: personal relationships, trust over information sharing, aligning the different goals and motives for participating [18].

Large industrial companies, have usually structured ways of collaborating with academia. Small and medium sized companies (SME’s) on the other hand are often challenged by lower educational level, dispersed needs and less contacts with universities compared with larger firms and may have particular needs of regional support connecting them to universities [18, 19], developed innovation centres should address these and support access to funding [20]. A developed collaboration centre can support translational processes in sustainable industrial development activities for long-term benefit.

4. Results and analysis

4.1. Regional conditions

The industrial symbiosis network in the west Mälardalen region started already in the eighties with an open district heating system in Köping municipality where industries could tap in their excess heat. In this system, mainly large users and suppliers of heat has been collaborating. In addition, manufacturing competence centres like Kuggcentrum and Mälardalen industrial technology centre (MITC) has been acting in the region as network for industrial competence exchange and technical development. Recently the energy network has extended to the three municipalities of Västra Mälardalen and initiated exchange of materials as well as sharing transportations and connecting competences.

For the Västmanland county of which west Mälardalen is one part (ca one third), according to Oxford Research [21] the largest industries (# employees) are; construction, steel, metalworking/manufacturing, vehicle and other machines, computer and electronics together with industry services. The construction industry is the largest industry, but only as big as in the rest of Sweden, while computer and electronics and vehicle and other machines has a significantly larger share than in other parts of Sweden. The most important specialisation (the industries with larger ratios than Swedish average ratio) is in the steel-metalworking-vehicle industry supply chain [21]. The county has a long history of development in the specialised areas metalworking/vehicle industry and electronics /computer industry. Although the rate of higher education in the three municipalities (<16,5%) is ten percent lower than the Swedish average (26,6%) [22], the potential for development of innovation and entrepreneurship is believed to be high in the whole county. Västmanland have several innovation initiatives supporting these industries (e.g. MITC, Robotdalen and Automation region are active in the region) with competence development, business development and industry collaboration research with university and research institutes. On the top 25 employers (>500 employees) in Västmanland the three municipality and the two biggest companies in Köping are on the list, all part of the UIS network [23].

4.2. Survey and workshops on collaboration over resources

The IUS collaboration overall was rated as active (3), mainly thanks to the collaboration around energy (heating and cooling). Material and transportation collaboration mainly take place through regular logistic and waste management providers although other initiatives rated as initialised (2) does take place. In Table1 below is presented results of the grading inspired by Golev’s et al. [6] maturity model, according to survey answers and workshop discussions. Table 1 also include over 10 proposed symbiosis solutions generated during the project. A business model must be developed for each solution where resources are shared to provide incentives for long term collaborations. More research is probably required related to such models. In the region, many actors see value in the UIS and have a positive attitude towards the UIS generated solutions.

Table 1. Maturity evaluation

Area	Level of maturity (1-5)	Potential, unexploited resources in UIS judged by survey answers
UIS - general	**2-3**	Initiatives exist mainly energy UIS. Potential for high maturity degree exists.
Focus area		
Transportation - general	**2**	Unused resources related to transportation available, local port & railway
Boat transport	**2**	Harbour in Köping is low exploited, no load balance of incoming and outgoing shipping
Railway transport	**1-2**	Railway has potential to be more exploited
Truck with fossil free fuel	**3**	There are expanding local actors providing fossil free truck transport solutions
Material - general	**2-3**	There are recyclers/waste managers providing waste handling, near the region but not present on locally. Local recycled material flows are unexploited.
Metallic material	**3**	Recycling companies collect material in the region with operations near the region.
Electronic waste	**2**	Local dismantling companies exist but low level of exploitation.
Bio fuel	**2**	Waste that may become fossil free fuel from e.g. local agriculture has low exploitation so far.
Plastics and paper	**2**	Plastics and papers are not recycled to sufficient degree or economic profit. Development potentia exist.
Energy- general	**3**	Some local collaboration exists but the potential is much higher and therefore considered as unexploited.
Energy efficiency	**4**	Many companies work intensively for energy savings in their own facilities.
Solar energy	**3**	In the region, some have started using and many thinks of using solar energy to a larger extent. Local suppliers exist and the potential is high. Competence exists in the region for solar energy solutions.
Cold and heat waste	**2**	Local sharing of waste heat and cold are started being discussed. Distribute heating actors play an important role. Competence exists in the region for shared energy solutions.
Energy from charge stations	**2**	Some companies already installed charge, but common charge stations have been identified as a solution that is still unexploited.
Competence - general	**3**	The value and conditions for sharing experience and knowledge is rather high but still quite unexploited in the region.
Networks	**3**	Exist in the region
Cluster	**3**	Exist in the region
Community	**4**	The municipalities promote UIS in Västra Mälardalen and have appointed roles for engagement in the development and the strategy of the UIS, which result in a high grade of maturity.
Business models	**2**	Business model has to be developed for each solution which require competence to be available via the UIS Many actors are engaged and see a value in the UIS solutions put.

The hinders and challenges for each area was then summarised in Table 2. For development of more sustainable transportation such as shipping it is clear that national economic and regulatory hinders are large. Circular material flows may need more knowledge and innovation support to secure material quality, to raise awareness and commitment. Energy collaboration is mature but may advance if business model development is supported locally and awareness of economic and technical feasibility of new solutions is spread. Many solutions were discussed in the workshops and the local conditions and opportunities have to be visualised for local actors. The competence and innovation actors present in the region needs to enhance collaboration with the symbiosis network and develop and knowledge management further, aligned with the sustainable development goals of the UIS.

More than 50 physical interviews have been performed with different industrial actors. WS was held at two occasions with approximately 15 participants each. Around 75% of these were industrial related. The two half day workshops and interviews The two half day workshops resulted in around 15 suggestions for collaboration between the parties participating. None of these suggestions were believed to be concretised without the UIS workshops. The study has not been involved in any implementation initiatives

Table 2. Restricting challenges/area.

Challenge area	Yes/No	Challenges identified	Comment
Transports	Yes, for shipping	Engagement, regulatory frameworks	Lack of engagement from central management for local transportation solutions. Regulatory frameworks with national fees for shipping.
Materials	Yes, to some extent	Sharing of information	Knowledge and information of recycled materials and local actors providing competence and materials enabling effective local recycling/reuse
Energy	No	Competence and technical challenges	Competence and local technology networking bringing together existing technology for energy recovery for heating and cooling. Business models incentivising shared technical solutions. Competence on solar energy use.
Knowledge and competence	No	Information sharing	Innovation clusters and networks exist but can be more active in the UIS. The strategy with challenges and needs identified via the UIS.

4.3. Overall evaluation of UIS

Analysis of the survey results confirm that the UIS fits definitions of regional industrial symbiosis although the maturity according to Golev's et al. [6] model is rather low in some sub-areas. The potential of the UIS is regarded as high since all critical elements of UIS [3] are present in the studied UIS. The municipality are involved, large companies from industries with a long historical background in

The UIS is fairly mature and rated as *active* in the collaboration around energy. Material and transportation symbiosis is rather immature and rated as *initialised*. Competence and innovation collaboration needs further research but has high potential due to clusters and academic actors present in the region.

Analysing the critical factors mentioned in theory, points to high potential for continuous development of the UIS. In the UIS and connected networks/clusters both large and small companies are present. The support from high competence bodies as cluster and academic partners exist. Finally, the project has used physical meetings via WS led by persons that have the role to catalyse and facilitate collaborations and identify common solutions providing win-win situations for resource efficiency on a holistic regional level. A common strategy with challenges and needs identified via the UIS. Potential exist in community engagement. Participants at the WS where highly engaged and fulfil criteria of actors' necessary for success of the UIS.

5. Discussion

The studied UIS is active especially in sharing energy resources. The collaboration in energy can be used to develop also other areas and start sharing of transportation and material for reuse or recycling. Most important have been the physical meetings, but also the common view on the needs, in this case locally driven resource efficiency. At least three solutions proposed are mature, and the implementation of these should be studied in future work. All in all, participants in the UIS is positive to collaborate towards common solutions and confirm the importance of UIS to discuss and realise such ideas. Hinders for such solutions outside the UIS are often organizational, that the solutions are not related to core business and that actors are not in each other's regular networks. Participants at the WS and interviews will continue to be active members of the UIS.

the UIS can continue to catalyse innovative business in a proactive way with continuous workshops. It would be advantageous if the innovation support organisations take an active part in this with their possible connections to Mälardalen University, and students with competence in sustainable industrial development. In addition, when regulatory barriers exist, the UIS can be a way to reach regulatory bodies. The UIS-collaboration may also be a way to attract new companies working with recycling and reuse locally.

Industrial symbiosis development need means to support sustainable development innovation for both large organisations and SME's. Developed collaboration centres like MITC and others, with firm foundation both in university and industry, can support translational collaboration [18], and development. By organising the collaboration towards sustainability into development programmes, could give SMEs a connection path into the UIS, the university and funding innovation projects.

Innovation support, face the same challenge as sustainable business development in PSS and UIS: It is a matter of making involved parties build collaboration which have some barriers. These barriers can be; lack of community awareness, cooperation, information over the shared resources or commitment to the common sustainability development goals. Such barriers can be overcome by UIS activities focusing on increased trust and transparent communication within the network. One specific barrier for UIS development is that especially large companies focus on core business, while UIS often try to utilise non-core resources. It is a challenge to overcome this. However, by experiencing the engagement in the UIS workshops, the authors hypothesise that the UIS can offer solutions to problems not only addressing core business for one company but for the whole network, for instance resource efficiency including personal resources, material resources logistic and energy issues.

As answers to the research questions this study shows that UIS criteria and maturity model can be mapped with surveys and interviews complemented with workshop discussions (RQ1a). The evaluation lists with strengths and challenges for each area is useful for strategy (RQ1b) The most critical factors for further development are how to achieve trust, share information and increase knowledge and awareness in the community(RQ2). One important way to catalyse solutions is to perform workshops where actors can initiate contact(RQ2).

During the course of the study the criteria for establishing UIS by Mirata [3] and the barriers described by Golev et al. [6] has been confirmed by participants. All together this case study at large confirms findings in previous industrial symbiosis studies [3, 4, 6, 11, 14].

6. Conclusions

This paper presents the current state and potentials of the UIS, Västra Mälardalens industrial symbiosis. The UIS goal is to support sustainability in terms of resource efficiency in relation to personal and competence, materials, transport and energy. Collaboration challenges and needs have been identified. Evaluating the UIS concludes that a great potential exists in via the community engagement and actors fulfil criteria's necessary for further development of the UIS. The personal meetings between people not usually doing business together has generated discussion and initiatives for solutions that would not otherwise be developed.

Based on the surveys the status of the UIS is evaluated as 'active' but not fully developed to 'forming the future' yet. Potentials based on a survey and workshops together with statistical background data shows that the region has large potential to develop the symbiosis with active companies and municipality as well as access to local innovation support. The UIS have potential to be acting as innovation catalyst supporting companies to go beyond core business development. The study contributes with confirmation of previous research and verifies critical elements of an UIS such as a mix of large and small actors, innovation support and competence but also physical meetings and appointed facilitating roles for UIS initiatives. It give qualitative insights into the development of sustainable innovation and business support.

Acknowledgements

This paper acknowledge Vinnova funding from Re:Sources program for development of industrial symbiosis. The work has been performed in collaboration with the Initiative for excellence in production, XPRES, and with circular material flow research within the advanced area of transportation at Chalmers university.

The authors contribution is as follows (where MK, CJ and AG are the authors initials): Theoretical background: MK, General methodology: MK, Empirics; Regional history and statistics: MK, Survey development: CJ, MK, AG. Survey analysis: CJ, AG, Workshop discussion, MK CJ, Workshop coordination and interviews AG, Analysis & Discussion MK, CJ.

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