METHOD FOR DEVELOPMENT OF SUSTAINABLE RELATIONS OF MANUFACTURING COMPANIES IN INDUSTRIAL ESTATES

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Abstract
Production companies are mainly optimizing sustainability of their processes based on requirements in resource efficiency and energy consumption. During the project “HoliPOrt” it was analysed how a network for long-term collaboration of enterprises can be implemented. The hypothesis is that an optimized sustainable network of manufacturing companies can only last, if interrelations of partners create benefit for all. Therefore, companies and their properties need to match to support working dependencies. The utilization of system dynamics in the HoliPOrt-approach supports a detailed evaluation of companies and current industrial estates. The concept approach is adaptable to existing locations and its situation. By analyzing the existing interdependencies, it is possible to integrate further levers for long-term sustainability of local collaboration of manufacturing companies.

Keywords:
Sustainable development, production networks, interdependency creation.

1 INTRODUCTION
Manufacturing companies in an industrial estate are usually working independently. There are many reasons for this, but the major factor is the lack of knowledge of the others’ business and challenges. Based on that, the authority or administration of the estate should support symbiosis or at least a better understanding of each other to create a common vision for sustainability. However, the administration or authority has an even smaller knowledge of the individual topics of the companies. Therefore, these units have difficulties to support the procedure for a suitable matching.

2 MOTIVATION
The demand for resource efficiency and sustainability in all economic fields has grown strongly in the past. Especially in the last years, a change of mind-set took place up to highest political leaders. New regulations have been established to reduce emissions for the future [1]. Additionally a change in customer requests and requirement setting is identifiable. Influential trends are individualisation and smaller numbers of products with same specifications. The smaller lot sizes result in more effort to set up the production and providing the suitable skilled persons for high quality products.

To address the mismatch of demands and necessary efforts, new ways of organising production are needed. The increase of collaboration between companies can support bridging the gap between effort and efficiency. Furthermore, symbiotic chains may support the consumption of resources by enterprises because the effectiveness of utilization is optimizable. Waste and emission can be reduced in long-term networks by providing an overall benefit for all instead for just one or few.

In the research project HoliPOrt (Concept of a method for a holistic development to resource-efficient locations of manufacturing companies) one target was to provide a supportive method to create a framework in which symbiosis of companies, especially manufacturing companies, can be developed.

3 METHOD FOR MATCHING APPROACH

3.1 Research method
During the Research project four stages were proceeded. In a first step an analysis on existing industrial estates was done. Based on this analysis, an appropriate approach for a categorization was done. The categorization was done for the industrial estates and the companies. This was followed by the examination of dependencies and interrelations with respect of resource efficiency. This was analysed on facts as symbiotic relevance, optimal utilization, reduction and re-use. This was the base for a definition of relevant date required for a description in a dependency models. Database have been analysed to find adequate data sources to provide working models with respect on effort for assessment, quality and usability of the data. In the end, an evaluation method was designed to realize an elaboration of symbiotic partnerships. The idea was to develop an evaluation method usable for different peer groups, which leads to a three level approach. Next to research of documents, workshop with experts have taken place. Different groups of experts were involved, interdisciplinary expert workshop as well as specific expert of a certain field. This allowed the capturing of a wide range of knowledge and experience.

3.2 Method for matching approach
Industrial estates have a life cycle. Based on that life cycle, the matching approach will have a major impact in phase development and utilization [2]. The speciality of this phase in the life cycle is that two main stakeholders with their aims can be identified.

1. Authority or administration office of the estate – Their target is the creation of a working ecosystem of companies within the estate. Companies occupy all existing areas and the companies get as much support for their business as possibly can be provided by the office. Secondary target can be the transformation of the industrial estate to a sustainable and ecological positive system.

2. Manufacturing companies and other enterprises as participants in the estate – Companies are focused on their business. Depending on the business model,
they focus on producing goods or providing services with the target to generate profit. A focus on sustainability or ecological procedures is mainly depending on regulations or societal pressure during doing business.

Due to the points above, the administrative units do not have a general working approach to support symbiosis. Additionally they do not have a common understanding about the way business is done in the companies in their areas. This leads to the requirement that the approach need to support different level of details in analysis and support for matching procedures.

Enterprises have different requirements due to their business model. It is required to create a generic abstract model of an enterprise with focus on manufacturing. An easy way to describe a production company can be done by an input-throughput-output model, shown in Figure 1. For companies the efficient use of resources is increasing in importance because the competition about resources is growing as well as the awareness of the customer towards sustainable production and processes during the product creation. The employed model was adapted to efficiency in use of resources. Based on that all relevant input and output factors have been raised and evaluated towards their impact on resource efficiency. This approach is always the base for the compilation of the matching details.

The inputs in the created transformation model are raw materials, auxiliary materials, third-party products, tools, electric energy, thermal energy, process water, drinking water, information, employees and customers. The throughput as transformation of input to output can be summarized in six main fields: material, technology, energy, water, data and human. Usually water is part of material but based on sustainability the resource water is becoming more and more important [3]. In context of industrial operations, humans are often integrated in resources. However, with respect to changes occurring by the digitalization this is not suitable anymore. Humans will act more often as decider than as operator because the processing will be done by intelligent machine controls. There is a change from resource to production factor [4]. Data and technology are already important factors in manufacturing. However, the importance will increase even more in the future [5].

Figure 1. Input-throughput-output model.

4 MATCHING APPROACH – DIFFERENT DEGREE OF DETAIL

The matching of companies in new or existing parks is possible in a different degree of detail with variable need of competency. Based on the research, three levels of complexity have been identified which are the base for the developed degrees of detail in the matching approach. The three levels can be defined as entry level, medium complex level and expert level. Each level may use data and results given from the previous level, if available. Based on that is the method is consecutive but each level is applicable alone, too.

4.1 Entry level

The entry level is the first step in finding suitable matches between companies and the estate they are in. The idea is to find matching units based on a framework. Aim of the match finding is the improvement of possible collaboration between the units with benefit for both. Important are conditions of the surroundings, the industrial estate. The suitable matches can be identified based on a classification of both the industrial estate and the enterprises. Therefore, a categorization is required.

Basic concept

Firstly, the industrial estates need to be categorized. For this categorization, six fields of relevance have been identified [6]:
- Environment
- Employees
- Services and service infrastructure
- Infrastructure
- Enterprises
- Information / communication

Under incorporating of these categories five major types of estates have been identified. The five types can be sorted in simple diagrams showing their specifics the ground size and human density based on available ground space (Figure 2). These types of estates can be specified in three independent sub-categories which describe the ownership, the concentration on environment friendliness and the existing of additional services.

Figure 2. Example for sorting the five main types based on criteria.

Secondly, the companies need to be put in categories as well. Based on common categorizing approaches the respective factors have been reduced to three fields (Figure 3). It was required to reduce the degree of freedom and the complexity because the number of potential company types would have been too big. Based on resource efficiency as scale the following categorization is a result:
- Tech Industries
  These companies are producing complex products and product-service combinations. These companies are usually integrated in later steps of the supply chain and...
use different suppliers. By technical-economic categorization these companies are technology-intensive or machinery-intensive.

- **Heavy Industries**
  If the products are simple or single parts and the production is energy consuming the company can be categorized as Heavy Industries. The products are rarely combined with wider service offers.

- **Light Industries**
  These companies are producing simple products and single parts with material-intensive processes. Services are seldom created as offer enhancement.

- **Service Organisations**
  Enterprises providing services, digital or physical can be called Service Organisations. These companies can be categorized as knowledge-intensive or personnel-intensive.

- **Transportation Organisations**
  Transport can be described as material-intensive. The offers of these enterprises are physical services.

- **Digital Organisations**
  These organisations are providing digital products, which are usually enhanced by services. The offered products are complex and the processes are technology-intensive.

- **Innovative Organisations**
  Depending on the type of product – digital or physical – the companies can be either service enterprises or manufacturing companies. The product itself is specified as product-service combination and the amount of service is high. The processes are knowledge-intensive.

- **Mixed Organisation**
  In the case the enterprise cannot be put into one of the categories above, it is categorized as mixed organisation.

**Evaluation and matching approach**

Two different matchings can be processed. Either a matching of a company to an industrial estate is possible or the matching between two companies can be performed.

For matching a company to an industrial estate, the six fields are relevant. All offers and demands of the industrial estate in the six fields will be the base for the matching evaluation. After all these topics are put together, the company is analysed with regard to specifications corresponding to the different aspects. Based on that, it is possible to evaluate the fitting characteristics. The evaluation can performed simple (just positive = 1 or negative = 0) or it can be performed more differentiated (an evaluation scale is used). If a decision is needed which company fits better, the higher result points to a better matching. Otherwise, it is possible to define a minimum level to be reached during the matching evaluation. A possible example is stated in Table 1, see next page.

In case of matching two companies, the focus is set on the three fields (product, type of company and cooperation) identified for company categorization. The further procedure is similar to the company-estate-matching stated above.

**4.2 Medium complexity level**

The medium complexity level is using the same approach but the methodology requires more details. Based on the categorization the enterprise is investigated more precisely. To do that a management approach is used. Nadler and Tushman developed an organisational behaviour model, which is used in its basic form for the analysis [6]. It is called congruence model. The model is consisting of four main areas – strategy, input, mechanism and output. Each area has sub-categories to describe the organisational construct in the required degree of detail. Based on that, the model was applied for both, the companies as well the industrial estates. In each case the sub-categories are different.

**Basic method**

Firstly, the companies need to be described. For the definition of sub-categories, the focus on resource efficiency is essential to have optimal analysis areas. As seen in Figure 4 the input area is consisting of material and energy as resource factors. Furthermore, input consists of knowledge, requirements and capital because these factors may influence the potential transformation procedure. As top-down approach, the strategy is used to orientate the organisation. Sub-categories are the vision defined by the management and the leadership by the management personnel. Furthermore, regulations given by the authorities have an influence as well. Mechanisms are the bottom-up approach whereby the employees, the existing tools and implemented procedure have the biggest influence on the organisation and its performance – even towards resource efficiency. The output is the result of the transformation performed in the organisation.
Table 1. Example for company-estate-matching.

<table>
<thead>
<tr>
<th>Field for Evaluation factor</th>
<th>industrial estate</th>
<th>enterprise</th>
<th>matching</th>
</tr>
</thead>
<tbody>
<tr>
<td>Infrastructure</td>
<td>Data connection</td>
<td>Glass fiber</td>
<td>G5 testing area</td>
</tr>
<tr>
<td></td>
<td></td>
<td>G5 testing area</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>Waste management</td>
<td>Bold</td>
<td>No special requirements</td>
</tr>
<tr>
<td></td>
<td></td>
<td>electricity</td>
<td>gas</td>
</tr>
<tr>
<td>Employees</td>
<td>Number of employees</td>
<td>Rural area</td>
<td>1000 employees</td>
</tr>
<tr>
<td></td>
<td></td>
<td>4000 inhabitants</td>
<td>300 employees specialized (electronic)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>10000 inhabitants in periphery</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Special knowledge</td>
<td>Training school (5 km)</td>
<td>Specialized workforce for electronic engineering</td>
</tr>
<tr>
<td></td>
<td></td>
<td>University of applied science (15 km)</td>
<td></td>
</tr>
<tr>
<td>Enterprise</td>
<td>Required land</td>
<td>Parking space, reloading site</td>
<td>Parking lots</td>
</tr>
<tr>
<td></td>
<td>Sharing potentials</td>
<td>Vehicle , restaurant, parking areas</td>
<td>Own property</td>
</tr>
<tr>
<td></td>
<td>Immaterialized products</td>
<td>Yes / no</td>
<td>Yes</td>
</tr>
<tr>
<td>Environment</td>
<td>Waste water load</td>
<td>Regulation for environment protection</td>
<td>Not existing</td>
</tr>
<tr>
<td></td>
<td>State-of-the-art in technology</td>
<td>Fully automated / manually</td>
<td>Manually</td>
</tr>
<tr>
<td></td>
<td>Acoustic emissions</td>
<td>Regulation of night tranquity</td>
<td>Day shift only</td>
</tr>
</tbody>
</table>

0 = bad match; 1 = good match

Relevant sub-categories are the product / the service itself as well as generated waste next to experience that it is gained during the transformation process and the wealth of the employees due to their earnings.

The adaption of the organisational behaviour model can also be done for industrial estates, as shown in Figure 5. For this means, the approach is different comparing to the enterprise adaption. Reasons for that can be found in the structure of an industrial estate, which consists of the companies in it. Due to that, input and output of the companies are part of the input and output of the estate and has an influence. The transformation process in the estate is differing significantly from the one of the companies. Reasons for that is the higher complexity. Furthermore, the possibility to influence change depends on the cooperation of the established companies. The other stakeholders, besides the companies, influencing the system have different aims, which is creating a multi directional development.

![Figure 5. Description of an industrial estate using the organisation management model.](image-url)

**Evaluating combinations**

The approach developed for the different congruence models is similar to the entry level. A matching of different parameters is been done. The method for the match is different. The model of the industrial estate is the framework where all existing enterprises are put in the centre. The concrete congruence model of the company is used.

With this completion all required input and provided output can be detected. This will be the base to find potential dependencies and collaborative connections. Furthermore, it is possible to detect needs and excess in each field. The gap can be used to evaluate enterprises searching for location. Additionally it is possible to balance the common strategy and motivation of companies in the long-term development. First guidelines for technology upgrades can be formulated as well.

It is important to create a detailed congruence model of each company. It is crucial to keep the degree of detail on the same level for each enterprise to provide a comparability. This is necessary to find the important gap and potential cooperation possibilities. The matching can be done on easy level just on qualitative base. Even more effective is a quantitative evaluation because then the required elements can be calculated.

### 4.3 Expert level

The information used in the entry level and medium complexity level can be used in the expert level but it is not necessary to do so. Reason for that is the different approach in the expert level. System dynamics will be used to describe the ecosystem of companies and the estate itself. System-dynamics have the benefit to work well for complex systems with many interrelations and interdependencies [7]. The visualization can be done by cause-loop-diagrams to provide information of the existing and relevant relations of each variable within the defined system [8]. For efficient and handy model it is required to define a border for the system. Otherwise the complexity is
causing trouble in two ways – errors by limited and different precision of equations and slowing down of potential calculations [9].

Creation of a qualitative model

After the borders of the model are defined the relevant variables can be identified. Within the project a generic model has been developed which can be used as base. The model was created by using aspects of different models towards sustainable development in manufacturing processes, as provided by the research group of Kibiri [10] and the Fraunhofer team [11]. However, the model as partly stated in Figure 6 needs to be adapted to the companies and the conditions of the industrial estate. If the entry level or medium complexity level has been used already, the existing sub-categories can be used as parameters. Otherwise, the variables need to be analysed and the model needs to be extended by missing variables.

The model shows the dependencies and its relations with each other.

Quantification of a qualitative model

When the qualitative model exists, it can be quantified. Than the model can be used to simulate different scenarios based on different conditions or even parameter sets. This may help the find better solutions for different ways of development.

The quantification is the building of equations based on relevant variables from the model. Due to the variables, the equation can be simple without any time dependency or mathematic functional relation or based on that. In Equation (1) an example for the developed system dynamic model is given. The example is about the emissions per hour based on traffic density and specific Emission value per participant.

\[
\dot{\text{Emit}} = \text{Emit} \times \text{Density} \times \text{Spec Em p part} \times 60
\]

(1)

This definition need to be done for all variables in the model. Some equations do already exist and need only be extended with new variable others need to be defined based on current information.

By using the simulation functionality, different scenarios are possible. It is possible to create different situations or define different conditions to get an insight of the possible differences toward the focused areas. Based on the simulation results the best suitable set-up can be found. Even if the best set-up is found, the model in this general stage can only give an indication for development goals. For a stronger reliability the provided model needs to be more concrete which has a strong influence on the complexity. Then a group of experts for different fields (e.g. production management, city planning, environment specialist, technology specialist and general management) should be incorporated to define a suitable system model.

5 CONCLUSION

The developed methodology is suitable for users with different expertise. Different stakeholders or teams of different faculties can use the approach. It is supposed to use the most advanced level of detail due to the existing expertise in the development team of the urban area or the industrial estate. Currently the only method is available. Supportive tools only exist in conceptual states. However, the method can be used without tool support.

By using the presented method, an improvement of the industrial estate is possible. It will provide support in two directions. On the one hand the understanding of the enterprises situated in the estate towards procedure towards resource efficiency in collaboration. Furthermore, the improvement procedure during development of estates can be done more structured. Therefore, it is the base for synergy and symbiosis in an industrial area where sustainability by cooperation needs to be developed and implemented first. Only a structured long-term orientated development will lead to sustainable symbiosis. To control the improvement process a monitoring on regular bases is required to do an assessment. The assessment is the base for decisions on improvement measures.

6 OUTLOOK TO FURTHER WORK

The developed method will be used in a project for sustainable development of urban regions. Therefore, the approach needs to be applied to really existing systems to verify the developed system dynamic model. Furthermore, it is necessary to improve the mathematic quotation in the model. In following projects, the model will be expanded to integrate further aspects that are relevant for the surrounding environment. This incorporates topics like mobility, supply, distribution and energy as major fields.

Other projects with similar topics are about to be planned or first discussions are started. The focus area of the projects is urban orientated manufacturing and approaches of distributed production networks that are strongly interacting with their outer environment and urban surrounding.

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8 REFERENCES


