Zijm Consortium: Engineering a Sustainable Supply Chain System

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***Abstract*— In this paper[1] we address one of the current major research areas of the *Zijm consortium*; engineering sustainable supply chain systems by transforming traditionally linear practices to circular systems. We illustrate this field of research with a case consisting of a network of three firms *Willem (W), Hendrik (H), and Maria (M)* and show how the practice of application-oriented state of the art technology transformed their linear relation to the circular *Zijm consortium*. The work shows that through inspiration and knowledge transfer in the versatile picturesque Twente Region, a group of future generation researchers are shaped.**

I. Introduction to the Case

Today's competitive business environment demands ever more collaboration between organizations. In this paper, we review and discuss the establishment of the Zijm consortium which, today, is widely recognized as an example of sustainable intra-supply chain collaboration. The Zijm consortium consists of three companies: spare parts manufacturer (supplier) *Willem* (W), 3D printing company *Hendrik* (H), and service provider firm *Maria* (M). In the following, we discuss the original dependencies between the three companies. Therefore, we review how the relationships between the companies were initiated.

Service provider M, established in Amsterdam, is responsible for the upkeep of numerous capital goods. Therefore, M maintains a wide variety of spare parts to provide its customers with high service levels. The management of associated inventory costs and risks constitute the core competence of M, and is coordinated with help from the Dutch Institute for Advanced Logistics in Breda. Most spare parts are sourced from the spare parts manufacturer W headquartered in Eindhoven which is formally arranged by a long-term purchasing contract between both organizations.

3D printing company H, a relatively small business originated from the island of Texel, was interested to establish a new business division in the spare parts printing market. Originally, H became aware of the relationship between spare parts manufacturer W and service provider M with help of an industrial symbiosis information systems (see details in section II). Interested to further explore business opportunities with both organizations, 3D printing company H offered M a free assessment of their spare parts assortment with the promise to identify spare parts which are possibly interesting for the production with 3D printing technology. For this purpose, H employed a top-down approach to rank the service provider's spare parts according to its economic benefit if applying 3D printing [1]. Then, in-house 3D printing experts assessed the technological feasibility of the most promising spare parts which resulted in an overview of promising business cases at service provider M. Encouraged by the unforeseen potential of 3D printing technology for their business model, service provider M carried out various in-depth studies. For example, M evaluated several strategies to move to 3D printing technology and whether a parallel usage of conventional and 3D printing methods may pay off as well [2], [3]. Also, M found that 3D printing may facilitate the redesign of spare parts. In particular, the redesign of spare part assemblies with fewer, but therefore more complex components sparked the interest of M. For instance, M believed that a reduction of assembly steps would reduce replenishment lead times and thus reduce safety stock requirements. Follow up studies clarified that associated trade-offs are more involved than originally anticipated and thus require an extensive costs analysis [4].

[1]This work is dedicated to Prof. Dr. W. Henk M. Zijm—professor of industrial engineering and former Rector Magnificus of University of Twente, The Netherlands—for his retirement and 66th birthday.

II. Identifying collaborative opportunities

New technologies such as 3D printing technology often redefine the industrial symbiosis relations between organizations. In order to identify and leverage on these changes it is typically advisable to establish information systems which inform other organizations about the business process supply and demand. In particular, such information systems may function as a marketplace for industrial waste [5]. Potential business partners become more visible and companies are encouraged to re-consider the re-use of waste materials, abundant services and under utilized capacity. However, the booming success of such systems resulted in such a large number of available waste items that match-making between the companies is needed to facilitate synergy creations. Smart algorithms [6] appeared to be the suitable solution to identify the potential relationships based on the preference models and preference similarities of industries. Having multiple synergies opportunities suggested to form a relations allowing companies to assess which configuration of a cooperation has a high probability of success to form a sustainable industrial symbiotic relation. This results in a consideration of additional support tools within the system in order to support among others the coordination, the contracting and the assessment of fair cost-benefit sharing schemes.

III. Supply Coordination and Win-Win Contracts

Service provider M is aware that it is not possible to fully rely on 3D printed spare parts. Some parts are simply not producible with 3D printing technologies and others are demanded in such high quantities that production with 3D printing is infeasible at this point in time. So, M remains dependent of spare part manufacturer W. Unfortunately, if service provider M wants to change the terms of his contract with spare parts manufacturer W—for example to decrease the order quantity— he needs to pay high penalty cost. Also, W demands high license fees from 3D printing company H if H were to produce the companies spare parts. As a result, a collaboration appeared uneconomical at the beginning. In particular, spare parts manufacturer W would need a strong incentive to refrain from previous agreements with service provider M and to provide spare parts production rights to 3D printing company H.

Aware of this problem, company H initiated a search for innovative techniques that would strengthen its bargaining power and position its business more central in a possible collaboration between companies $W.H.M$. Most promising appeared a cutting edge technology which would allow H to modify and repair expired and broken spare parts using 3D printing technology. This assessment was based on following deliberation: Service provider M has plenty of expired and unrepairable spare parts which are discarded at spare parts manufacturer W in order to obtain raw materials. Yet, W would prefer to reuse most of these parts as it would present itself as cheaper and more sustainable sourcing option. So, 3D printing company H approached spare parts manufacturer W and offered the repair of broken and expired spare parts. In return, H requested a production license which would be valid if service provider M would encounter shortages. So, company H would function as emergency supplier for service provider M (as discussed in [7]), and at the same time, would repair various broken and expired spare parts that come back to spare parts manufacturing W [2]. All in all, Figure 1 depicts the new supply chain design:

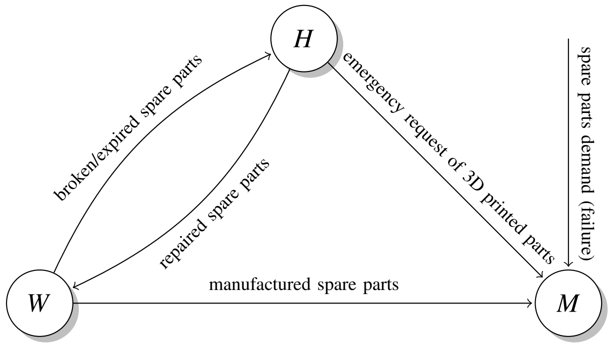

Fig. 1. Zijm Consortium: A sustainable supply chain among Spare Parts Manufacturer $Willem(W)$, 3D Printing Company $Hendrik(H)$, and Service Provider firm $Maria(M)$.

The new supply chain structure (illustrated in Figure 1) corresponds to the so called *industrial symbiotic networks* [9], [10] in which industries collaborate to realize lower material and energy footprint. In the next section, we discuss the principals applied by the companies W, H, and M to guarantee the fairness and stability of the Zijm consortium as a sustainable industrial symbiotic network.

IV. Allocation Challenges and Ways Forward

One aspect that may negatively influence the sustainability of industrial collaborations is the lack of efficient methods for allocating obtainable benefits among firms. In principle, such collaborations are a form of *coopetition* in which firms cooperate to materialize a collective benefit but also compete to gain a larger share individually. In the following, we elaborate on the methods that the Zijm consortium applied to tackle this allocation challenge.

The Zijm consortium is well-known as a successful realization of the concept of circular economy in the industrial context. In this consortium, fair and stable allocation methods are integrated into contract settings. So, it is guaranteed that the benefit share that will be allocated to each firm (1) is higher than what they can gain individually (to guarantee the stability of the relations) and (2) reflects the marginal contribution of each firm to the collaborative practice (to guarantee the fairness of the relation). As discussed in [10], [11], while in 1-1 relations employing the game-theoretic notion of Shapley-based allocation can guarantee both the fairness and stability of relations, for industrial symbiotic networks—such as the Zijm consortium—governments' support is essential. Such supports are to foster the establishment and stability of the network by means of introducing monetary incentives.

Finally, we highlight the use of normative coordination mechanisms—as suggested in [9]—in the Zijm consortium. Employing such flexible agreement technologies enabled monitoring firms' commitment to the consortium contract and introduced dynamic controlling mechanisms to nudge the consortium's behavior towards desired behaviors—from an environmental and socioeconomic point of view.

[2] See [8] for a comprehensive analysis that captures spare parts planning and coordination of service engineers with partial backlogging.

V. Conclusion

As illustrated in this work, Zijm consortium is a successful realization of the concept of circular economy in the industrial context and similarly represents a sustainable industrial symbiotic network. This is achieved by employing—collaboration identifying information systems, asset maintenance techniques, smart dynamic contracts, and normative coordination mechanisms—in an integrated manner. Zijm consortium's experience motivates further research on: (1) "improving effectiveness of spare part supply by additive manufacturing as dual sourcing option", (2) "the influence of knowledge in the design of a recommender system to facilitate industrial symbiosis markets", (3) "contracting in multi-echelon after-sales service logistics", and (4) "modeling industrial symbiotic networks as coordinated games".

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