An interdisciplinary cooperation network for the optimisation of sustainable life cycle buildings

Julia Selberherr[1], Gerhard Girmscheid[1]

Abstract

Sustainably optimised life cycle buildings as complex systems require, in addition to a good architecture and flexible usability, the integration of several interdependent subsystems. As current design and construction processes are linear and highly fragmented they are inappropriate. Cooperative networks have been identified as appropriate means for the development of optimised systems in various industries. According to a survey conducted at ETH Zurich the project-specific integration of key capabilities for the development of the overall system enables the optimisation of performance and costs which results in a perceivable surplus value for the customer. Therefore a research project has been initiated to investigate the use of cooperative networks for the optimisation of sustainable buildings as complex systems with particular regard to reducing opportunism, keeping competition up within the network to ensure market conformity of offers and generating a perceivable surplus value for the client across the life cycle. This paper focuses on a new cooperative business model, which is theory-led deductively developed. An interdisciplinary cooperation across trades and stages of a building's life cycle masters the temporal and technical interdependencies in a building project through the project-specific integration of the different subsystems. First, the objectives of the participating enterprises are analysed and then the objectives of the cooperative network are consistently derived from them. Then, the network organisation model, consisting of a cooperation network and activated project networks, is presented. Next, the process model is explained, describing the setup of the cooperation network and the operation of the basic service offer as well as possible transformations. In the last section the roles and required capabilities, particularly of the system integrator, are discussed. The new, systematically structured business model enables small and medium-sized companies to pursue a differentiation strategy by jointly creating sustainably optimised life cycle buildings.

Keywords: business model, cooperation, partnering, sustainability

1. Introduction

The building industry bears an enormous potential for sustainability optimisation, which has been recognised but not seized yet. The existing building stock globally causes 30% of total CO_2 emissions and 40% of total energy consumption (United Nations Environment Programme 2009). Furthermore, the building industry consumes with 3000 Mt/a, about 50%

[1] Institute of Construction and Infrastructure Management; ETH Zurich; Switzerland; selberherr@ibi.baug.ethz.ch.

of the total material consumption, more material than any other economic activity (Pacheco Torgal and Jalali 2011). In addition, design and construction processes are highly fragmented and strongly focused on initial investment cost and are therefore inapplicable for the development of sustainable optimised buildings as complex systems (Girmscheid and Lunze 2009). A survey conducted at ETH Zurich identified cooperative networks as appropriate organizational structure for the development of holistically optimised systems in various industries (Lunze and Girmscheid 2009). Drawing on the experiences of cooperation networks for the optimisation of systems in other industries, a research project was initiated. The project's objective is to seize a cooperation network and project-specifically integrate the key capabilities for the optimisation of a sustainable building as complex system.

2. Research approach

A new cooperative business model is developed to overcome the linear, highly fragmented design and construction processes and to enable construction companies to master the required cross-linking of capabilities and know-how. This paper proposes a systematically structured model for sustainable life cycle service offers in the building industry. The essential innovative elements of the new cooperative business model are: A holistic **sustainable project-specific optimisation of the building as overall system** with regard to life cycle costs supplemented with **guarantees covering the operating phase** through the **creation of synergies** between different interdependent subsystems based on **repeated collaboration between the companies contributing key capabilities**, which drives continuous learning and improvement and can be used as incentive for cooperation compliant behaviour.

3. Research methodology

The development of the business model can be allocated in the third world of Popper (2002) and the hermeneutic science program with the objective of shaping the socio-technical world (Piaget 1973; Von Glasersfeld 1984, Girmscheid 2007). Triangulation (Yin 1984, Girmscheid 2007) through viability, validity and reliability is used to ensure the model's scientific quality. Viability is achieved through theory-led deductive modelling using systems theory (von Bertalanffy 1968) as formal scientific framework. The model's validity is ensured by the internal structuration with structuration theory (Giddens 1984) as meta theory and principal-agent-theory (Jensen and Meckling 1976). The model's reliability is achieved by testing its intended impact (target-mean-relation) using the principle of alternative interpretation.

Structuration theory aims at explaining the recursive relationship between structure and action. Sydow and Staber (2002) identify structuration theory as an appropriate meta theory for the analysis of inter-organisational networks, as the network structures are formed by actors and are continually reproduced and transformed, and thereby they are medium as well as result of social practices at the same time. Principal-agent-theory deals with conflicting interests of a principal and an agent in a contractual relationship. To reduce opportunistic behaviour of the agent principal-agent-theory is used and theory-led deducted recommendations for the design of the model are identified. Table 1 depicts three possible organisation problems, adverse selection, moral hazard and hold-up, and the corresponding

information problems, hidden characteristics, hidden action, hidden information, and hidden intention. Principal-agent-theory develops coping strategies to reduce the resulting negative effects for the principal. From these coping strategies recommendations for modelling the cooperative network are derived (Table 1), which are used as guidelines in order to reduce opportunism.

Table 1: Theory-led deducted recommendations for modelling (Picot et al. 2005)

Problems	**Theory-led deducted coping strategies**	**Theory-led deducted recommen-dations for modelling**
Adverse selection Quality characteristics of the agent are unknown (*hidden characteristics*) before contract formation (CF)	Signalling/ Screening	Standard partner selection process
	Self-selection	Internal competition based on competence
	Harmonisation of interests	Reputation
Moral hazard Actions of the agent cannot be observed (*hidden action*) or evaluated (*hidden information*) after CF	Harmonisation of interests	Fair profit sharing
	Monitoring	Open books, Continuous evaluation of collaboration quality
Hold-up Actions after CF can be observed but not prevented (*hidden intention* may exist before CF)	Harmonisation of interests	Provision of agreed collateral/ financial contribution

4. Modelling

4.1 Motivation and objectives

Mutual objectives are regarded as a constituent feature of cooperative networks in general (Sydow 1992) and also specifically in the building industry (Girmscheid 2010). A thorough analysis of a network's objectives has to take a multi-level approach starting at the objectives of the single enterprise (Mack 2003). On the **level of the single enterprise** the business objectives are made up by intrinsic and economic objectives (Kosiol 1966). The intrinsic objectives are directly connected to the production of goods or the provision of services as they specify the market offer in terms of type and quantity. Superordinate to these are the economic objectives which are concerned with the economic performance of the enterprise (e.g. maximization of shareholder value) and constitute its raison d'être. An enterprise will only participate in a cooperative network if it expects the positive contributions to its individual business objectives to be bigger than the risks involved resulting in a positive net-value.

Therefore any cooperative relationship is a means to contribute to the accomplishment of the objectives of the single enterprise. The **objectives for the cooperative relationship** specify how the cooperative relationship contributes to the objectives of the single enterprise. Different types of objectives can be distinguished (Picot et al. 2005). **Flexibility objectives** comprise efforts to be able to deal in a better way with quantitative fluctuations in demand as well as unexpected changes of a company's external environment. This includes the

objective of overcoming one's own capacity constraints in terms of production as well as financially. **Cost objectives** include reduced transaction costs and cost advantages related to the service provision. Gaining access to external know how through cooperation can also be subsumed under cost objectives. **Risk objectives** include endeavours to reduce the entrepreneurial risk and spread the risks connected to high investments among partners. Access to new markets through cooperation can also reduce risk through diversification. **Synergy objectives** aim at generating advantages in addition to the sum of all the individual contributions. Synergies are more of an instrumental character and may affect flexibility, cost, and risk.

The possibly conflicting objectives for the relationship from all cooperation partners have to be coordinated and eventually modified in order to generate a consistent system of **objectives of the network** (Maier 2002, Girmscheid 2010). This system is made up of reciprocal target-means-relations (Weber 1996). Once a consistent system of objectives for the cooperative relationship has been agreed upon, each single enterprise reviews its business objectives on the level of the single enterprise and adjusts them accordingly. In so far the objectives of the network have a retroactive effect on the individual business objectives. The intrinsic objective of the new cooperative business model is offering sustainably optimised life cycle buildings which constitute a perceivable customer surplus value. The economic objective of the new cooperative business model focuses on productivity, flexibility, and stability, primarily through the creation of synergies by inter-linking and project-specific integration of excellent sub-system capabilities. In addition a sustainability objective is agreed upon which helps to secure the long-term success and stability of the network (Girmscheid and Selberherr 2012). The basic service offer of the new business model pursues the use of sustainable, renewable or renewed building material, the energetic optimisation causing reduced energy consumption and CO_2-emissions as well as increased utilization and generation of regenerative energy sources, and provision of flexible usability.

4.2 Network organisation model

As the next step in the development of the model the organisational structure for the accomplishment of these objectives is specified. The cooperative network is led by the focal enterprise, the system integrator (SI) (Girmscheid 2010). This new business entity can be founded as a strategic business unit in a general contractor or any other company, for example in a heating, ventilation, and air conditioning company (HVAC), or as separate enterprise with the participating enterprises as shareholders. On the strategic level the focal enterprise as system integrator is responsible for the setup and management of the cooperative network as well as for the recruiting of cooperation partners as subsystem suppliers (SUSs). The new service offer is gradually expanded starting with a basic service offer, where investment cost is restricted through a guaranteed maximum price contract and life cycle optimisation is substantiated with predictions of the future energy consumption and model calculations using prior specified objective criteria to demonstrate the amortisation of increased investment cost over the building's life cycle. The essential components for the creation of client-specifically optimised buildings are the key capabilities which are contributed to the network by the subsystem suppliers and project-specifically integrated by

the system integrator. The remaining, complementary services are conventionally passed to subcontractors. For the basic service offer, for example, the subsystem suppliers are heating, ventilation, and air conditioning (HV), building envelope (BE), sanitary (SN), and electrical (EL) contractors. Later also energy contractors (EN), facility management providers (FM), security control technicians (SC), and building automation providers (AT) are included as subsystem contractors. A two-tier network organisation model (Figure 1), consisting of a cooperation network as basis for the setup of an activated project network, is chosen (Weber 1996, Mack 2003, Camarinha-Matos et al. 2005).

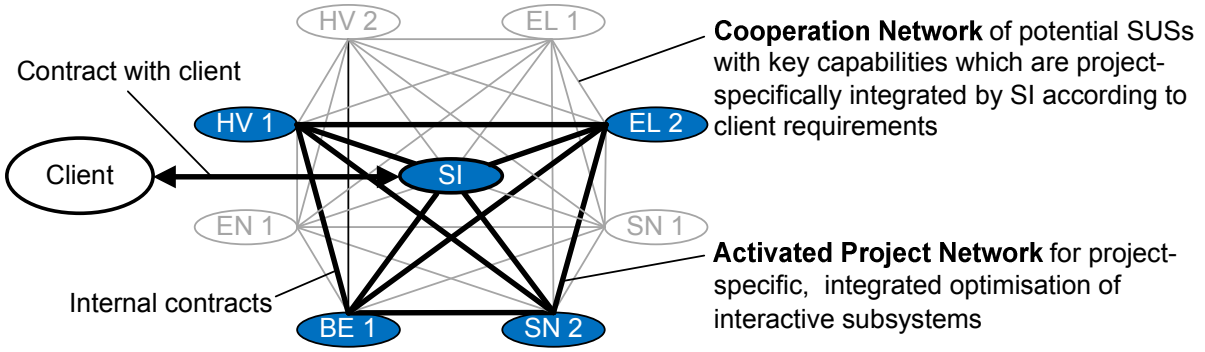

Figure 1: Network organisation model

4.2.1 Cooperation network

The cooperation network (CN) constitutes a pool of potential partners for collaboration in an activated project network. It is founded independent of any particular project and serves a prerequisite for the project-specific activation of a network. The objective, rational characteristics, like resources, competencies, and capacities, which qualify an enterprise as potential partner form the field of potential. The social factors and relational aspects, which make an enterprise a potential partner, constitute the field of social relations. These social and relational aspects can affect the personal level, the level of the enterprise, or the institutional level. The CN can be described as a function of the field of potential and the field of social relations (Mack 2003):

Cooperation network = f (field of potential; field of social relations)

From these fields the selection criteria for cooperation partners can be derived (Table 2). Strategic and organisational fit are vital for companies to belong to the field of potential. Strategic fit (Dyer and Singh 1998) concerns task-related criteria (Geringer 1991) and aims at the complementarity of technological capabilities in order to successfully create synergies. Companies as potential partners have to possess excellent technological capabilities which constitute the core competencies of the individual enterprises. The integration of these competencies is the core competence of the cooperation network. Organizational fit (Dyer and Singh 1998) concerns partner-related criteria (Geringer 1991) and subsumes organisational capabilities as well as the compatibility of situational and structural characteristics of the enterprise. Cooperative arrangements are more successful, if the partners are compatible in terms of characteristics like corporate culture, corporate strategy, process execution, firm size, and nationality (Müller 2005). The field of social relations aims at generating relational fit to build a basis of trust and is therefore connected to relation-related criteria like past experience and relational and reputational capabilities. In the

assessment of a partner's ability to cooperate, strategic fit constitutes a necessary condition, while organizational fit and relational fit are regarded as sufficient conditions (Mack 2003).

Table 2: Requirements for cooperation partners

Type of field (Mack 2003)	Field of potential		Field of social relations
Type of fit (Dyer and Singh 1998)	Strategic fit	Organizational fit	Relational fit
Type of selection criteria (Geringer 1991)	Task-related criteria	Partner-related criteria	Relation-related criteria
Type of capabilities (Hinterhuber and Stahl 1996)/characteristics	Technological (epistemic and heuristic) capabilities	Organisational capabilities and situational/structural characteristics	Relational and reputational capabilities, past experience
Type of connection (Heimeriks 2002)	Complementarity	Compatibility	Communality
Type of competence (Prahalad and Hamel 1990)	Core competence	Complementary competence	Complementary competence
Type of condition (Mack 2003)	Necessary condition for ability to cooperate	Sufficient condition for ability to cooperate	Sufficient condition for ability to cooperate

4.2.2 Activated project network

The CN serves as basis for the project-specific collaboration which is taking place in the activated project network (APN). As soon as a new client is acquired, his requirements are evaluated and an APN is founded. The APN is the level of value creation. Here the subsystem contributions of each partner are integrated to create a holistically optimised sustainable building.

4.3 Process model

The process model describes the operational structure of the new business model. A systematic multi-level approach with increasing level of detail considering main processes, modular processes and elementary processes is chosen (Figure 2).

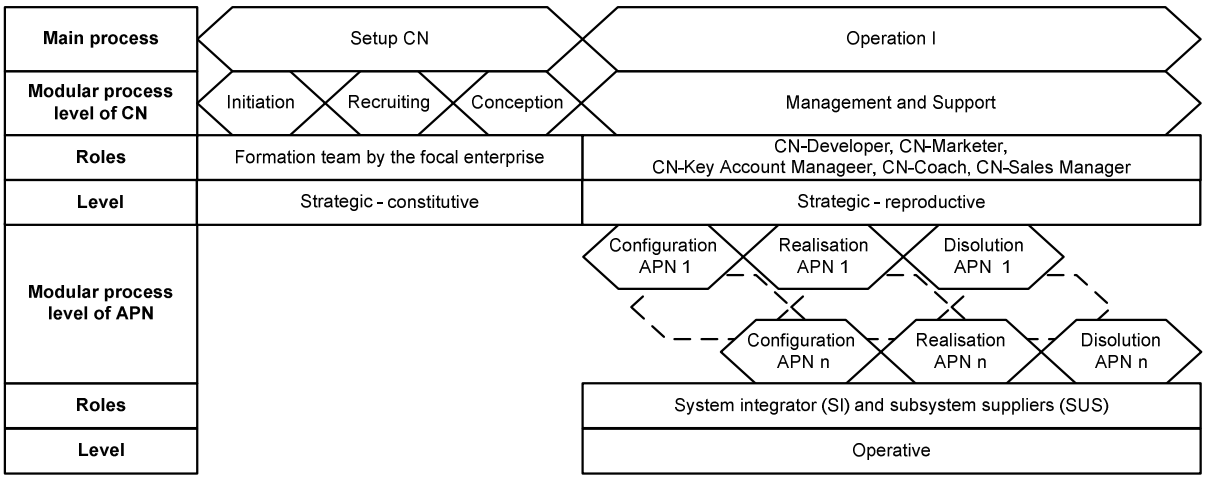

Figure 2: Process model depicting setup of the CN and Operation I

4.3.1 Setup of the CN

The *Setup of the CN* as main process concerns the strategic level of action. It encompasses the modular processes *Initiation*, *Recruiting*, and *Conception*. A formation team from the focal enterprise is responsible for the initiation and recruiting process. The conception process is undertaken together with representatives from the companies selected as partners, the CN members. The modular process *Initiation* prepares the recruiting of partners and conception of the CN. It includes the elementary processes shown in Table 3.

Table 3: Modular process: Initiation

Elementary process	Activities	Role
Formulation of business idea	Clarify client value and competitive strategy	Formation team
Environment and potential analysis	Evaluate market potential and possibly adapt competitive strategy	Formation team
Formulation of mission statement	Derive mission statement from underlying values of the cooperative network	Formation team
Definition of objectives	Define preliminary objectives of the cooperative network (intrinsic, economic, sustainability)	Formation team
Strategy planning	Formulate business strategy specifying service offer and detailed competitive strategy	Formation team

The next modular process, *Recruiting,* deals with the partner strategy. Enterprises with which the focal enterprise already has good experiences from prior business relations are most suitable as partners because they share a basis of trust and mutual understanding which is an important prerequisite for fair and non-opportunistic behaviour in the cooperation network (Girmscheid and Brockmann 2009; Girmscheid and Brockmann 2010). Furthermore, it is essential to discuss and resolve concerns raised by potential partners concerning the cooperation network, for example financial risk or knowledge drain. Table 4 depicts the elementary processes, activities, and roles of this modular process.

Table 4: Modular process: Recruiting

Elementary process	Activities	Role
Evaluation of required capabilities	Evaluate required capabilities, formulate selection criteria, identify and contact potential partners	Formation team
Application for CN membership	Write application specifying motivation for CN membership and select representatives	Potential partners
Selection of partners	Evaluate applications, conduct interviews, and select partners with strategic, organisational and relational fit as CN members	Formation team
Negotiation of code of conduct	Agree on common values, negotiate rules for cooperation based on mutual trust and commitment	Formation team and CN members
Communication of code of conduct	Communicate values and rules to employees to create shared understanding as basis for trust	CN members

The subsequent modular process *Conception* serves the specification of the configuration of the network with the CN and the APNs. It subsumes four elementary processes and ends

with the public announcement of the new service offer (Table 5). After the successful completion of the main process S*etup of the CN* the collaboration in APNs can be taken up.

Table 5: Modular process: Conception

Elementary process	Activities	Role
Revision of objectives and strategy	Evaluate objectives and strategy together with cooperation partners	Formation team and CN members
Definition of CN structure	Define organisational and operational structure of the CN with specification of tasks (management of the CN including admission of new members and support of the APN) and roles (CN-Developer, CN-Marketer, CN-Coach, CN-Sales Manager, CN-Key Account Manager) with attribution to actors	Formation team and CN members
Definition of APN structure	Define standard organisational and operational structure of an APN with specification of tasks and roles and negotiate standard contracts and financial contributions for an APN	Formation team and CN members
Formation	Launch the CN and announce new service offer to public	Formation team and CN members

4.3.2 Operation I: Basic service offer

The main process *Operation I: Basic service offer* encompasses the realisation of several projects. For each project a specific APN is set up, which is responsible for the successful execution. The CN performs a management and support function on the strategic level. On the operative level each project consists of three modular processes, namely *Configuration of the APN*, *Realisation of the APN*, and *Dissolution of the APN.* When a new project is acquired, the modular process *Configuration of the APN*, which concerns the tendering phase and comprises the elementary processes shown in Table 6, is initiated.

Table 6: Modular process: Configuration of the APN (tendering phase)

Elementary process	Activities	Role
Conceptual design	Evaluate client requirements and compile conceptual design	System integrator (SI)
Identification of required key competences	Identify necessary subsystems and prepare catalogue of required key competences	SI
Internal competition on terms of competence	Invite at least two contractors of each key competence from the CN to develop offer for specific contract thereby keeping competition up within the network to ensure continuous improvement and market conformity of offers	SI
Preliminary subsystem design	Develop preliminary subsystem design according to specifications of conceptual design	CN members
Selection of partners	Evaluate subsystem concepts and select best suitable partners as subsystem suppliers (SUS)	SI
Negotiation of internal contracts	Negotiate internal contracts based on standard contracts of the CN, specify organisational structure and attribute roles to cooperation partners	SI and SUSs
Preliminary system design	Integrate preliminary subsystem designs to preliminary system design and determine GMP	SI

If the contract is awarded to the APN, the focal enterprise represented by the system integrator is the contracting party of the client. The internal contracts between the subsystem suppliers create reciprocal guarantee obligations. The collaborative optimisation work in the execution phase starts with the subsequent modular process, *Realisation of the APN,* which consists of the elementary processes depicted in Table 7.

Table 7: Modular process: Realisation of the APN (execution phase)

Elementary process	Activities	Role
Launch of the APN	Arrange kick-off meeting to identify interfaces and analyse synergy potential	SI
Detailed subsystem design	Develop detailed subsystem design considering interfaces to other subsystems	SUSs
Detailed system design	Integrate detailed subsystem designs to optimised detailed design of overall system and identify synergies	SI
Tendering for subcontractor services	Tender for those parts of each subsystem which are passed on to subcontractors	SUSs
Subsystem execution design	Develop execution design of subsystem with regard to the synergies identified by SI	SUSs
System execution design	Create integrated operation scheduling and logistics planning to ensure optimised execution process in addition to optimised design	SI and SUSs
Execution	Execute construction works	SI and SUSs
Commissioning	Commission completed building	SI and SUSs

To ensure that lessons learnt and shared experience from the successfully completed collaborative venture are preserved for a continuous improvement of further projects, the *Dissolution of the APN* is modelled as separate modular process.

4.3.3 Further development: Transformation

The new service offer has to be expanded progressively in order to keep ahead of competitors and to sustain client satisfaction by generating an outstanding client value. The following expansions for the new service offer are suggested (Figure 3):

- *Life cycle offer I* delivers an energetic optimisation with performance guarantees of the entire building with particular regard to the interdependence of the building envelope and the HVAC-system.
- *Life cycle offer II* promotes holistic sustainable optimisation across the building's life cycle with extensive cost- and performance guarantees in the form of a service level agreement.

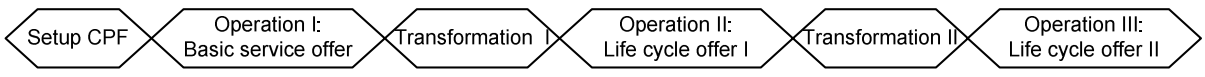

Figure 3: Main processes across the life cycle of the new business model

In order to successfully accomplish the expansion the CN has to actively promote an atmosphere of shared learning. Also new partners with the required capabilities have to be taken up into the CN. Furthermore, the process model for the APN has to be extended to the phases, Operation II and III, and financial arrangements for setting up provisions covering the guarantees for the operating phase have to be negotiated.

4.4 Key roles and capabilities

The key role for the success of the new service offer is that of the system integrator. He is the leading actor in the configuration and realisation of the APN. Whereas the subsystem suppliers contribute the component knowledge and technological capabilities concerning the subsystems, the system integrator is responsible for the integration of the subsystems and optimisation of the building as overall system. It is the system integrator's task to connect the interfaces between the interactive subsystems in order to obtain a client-specific integrative system optimisation. The capabilities required to successfully fulfil the tasks of the **system integrator** include both technical and managerial aspects:

- **System configuration capability** to transform clients' values and requirements into technical solutions consisting of a number of subsystems and to identify the relevant key capabilities corresponding to these subsystems
- **Evaluation capability** to identify the best offer for each subsystem and to ensure market-conformity of prices
- **System integration capability** to match the workflows of the subsystem suppliers and provide scheduling and technical coordination of the subsystems with the objective of optimising the building as overall system
- **Moderation capability** to conduct negotiations between partners and to perceive different points of view and incorporate them best possible in a solution concept

The **subsystem suppliers** are responsible for the life cycle optimisation of the subsystems with regard to interfaces to other subsystems during design and construction, and for the construction of the subsystems in compliance with cost, time and quality objectives. Therefore they need **excellent technological capabilities** particularly with regard to life cycle costs of the subsystems, function-oriented optimisation, and consideration of interfaces in terms of an integrated project delivery. Each subsystem supplier should nominate a **boundary spanner** who is the designated contact person for all activities and inquiries concerning the cooperation network. The subsystem suppliers excel due to the depth of their know-how relating to the subsystems, whereas the system integrator features an enormous width of know-how covering all the aspects which constitute a sustainably optimised building.

Further roles for the management and support processes on the level of the CN are:

- the **CN-Developer** who is responsible for the anticipation of future client requirements (market capability) and identification as well as acquisition of newly required capabilities (absorption capability),

- the **CN-Marketer** who establishes the new service offer on the market through a suitable marketing-mix and is responsible for advertising and sales promotion (marketing capabilities),
- the **CN-Sales Manager** whose task is the acquisition of new contracts (acquisition capability)
- the **CN-Coach** who is responsible for internal mediation, conflict resolution and joint problem solving (mediation capability)
- the **CN-Key Account Manager** who is in charge of client support and customer care (client support capability)

5. Conclusion

The theory-led developed business model takes a systematic approach towards the formation and operation of cooperative networks in the building industry. In this paper the concept of the model is outlined. Strategic, organisational, and relational fit are identified as prerequisites for successful cooperation. The network organisation model and the process model have been developed guided by design recommendations derived from principal-agent-theory. In the further development of the model the incentives for companies as well as individuals to participate in the cooperation network have to be identified and mechanisms to reduce opportunistic behaviour and to keep competition up within the network to ensure market conformity of offers have to be deployed. A balanced mix of trust and selective control mechanisms best ensures a harmonic coexistence of cooperation and competition within a network. Furthermore, it is vital for the success of the new service offer to develop the required capabilities connected to the key roles. This aspect underlines the importance of individuals, not only in the field of social relations but also in the field of potential, for the successful operation of the new business offer. The new business model enables especially small and medium-sized enterprises to pursue a differentiation strategy by contributing their excellent technological capabilities in a cooperative network with the objective of offering sustainably optimised life cycle buildings that are client-specifically created through the integration of interdependent subsystems.

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