

Design of a Rule-Based Network

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Abstract— Because of today's complexity it is unavoidable for most companies to manufacture via corporate networks. However, current network models yield a negative correlation between the favourable attributes efficiency and flexibility. In this paper a network form is suggested which lives up to today's requirements, offering both means of efficiency and flexibility. The network to be created must live up to the character of a decentralized network. It needs to serve exchange processes resulting from the economic and judicial independence of the network partners. Simultaneously, the new network form needs to incorporate the ability of being coordinated by rules so that it efficiently lives up to the complexity challenge. This paper presents approaches for both, the organizational design and process design of a rule-based network which is led by a network manager.

Keywords— network, process, rules, structure

I. INTRODUCTION

THE high complexity of technical systems leads to an increasing number of parties and required competences involved in the development and manufacturing process. More than ever these competences are provided in the form of development and production networks. Networks provide an essential tool for companies to ensure competitiveness in a very punctual way within a macroeconomic context [1]. Usually, these networks are coordinated by a network manager who is an active part of the network. Due to the high interdependences of the product components it is inevitable that the cooperation partners interact with each other and also with the network manager.

Present coordination theories are based on either a hierarchical network structure which results in a loss of flexibility or a self-organizing structure which might be more effective but is less efficient as the hierarchical structure.

In addition today's development and production environment is marked by high dynamics and unpredictability. Customers' needs change rapidly and lead to high costs for changes and adoptions of the products.

In the context of decentrally organized networks there is often a negative correlation to be found between the challenges of flexibility and span-of-control. Decentralized

organizations hold a high potential of flexibility and response time. In addition to this effectiveness potential a minimum of span-of-control is required in order to reach the favorable efficiency ([2],[3]). The challenge is based on the trade-off between an increased flexibility, achieved by giving decision making rights to more than just one entity, and the extent of span-of-control. This increased flexibility only comes at the cost of a lower span-of-control. The decreased span-of-control has negative effects on the achievement of the overall network optimum and leads to a lower efficiency of the processes. This directly leads to higher transaction costs. Figure 1 illustrates the mentioned trade-off effects.1.

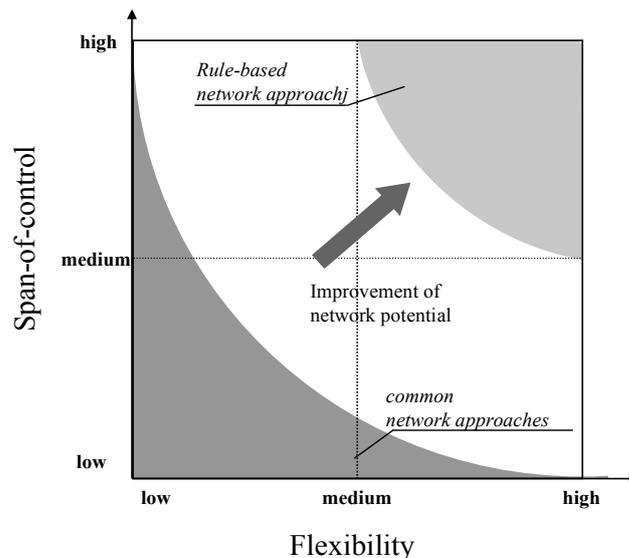


Fig. 1. Trade-off between flexibility and span-of-control

Taking the mentioned problems into account, it becomes evident that there is an urgent need to overcome the outstanding challenges.

In contrast to existing approaches in theory and practice this work intends to present a rule-based, implicit guidance concept which functions as a framework ensuring the protection of interests of all network parties in the sense of a network optimum.

II. STATE OF THE ART

Accounting for the interdisciplinary character of networks, theories of various disciplines have to be analysed with respect to their fit as they might be useful for the network design. It is important to note that these theories are not exclusive but rather offer different perspectives to the subject of matter.

A. *Negotiation and rule-based coordination approaches*

Lu's coordination model offers an engineering perspective, stating that all engineering activities take place in the context of socio-technical problems and therefore are marked by a coordination pattern. Lu adds aspects of communicative coordination, negotiation and decision-making to the value creation process. Experimental-economic theories, e.g. auction theory, help in simulating the behavior of these coordination systems. [4]

Based on the coordination theories and specifying these, there are first research efforts dealing with the rule-based coordination of social systems. However, the rules presented in these approaches are only useful to a limited extent for the suggested concept due to their generic character.

B. *Approaches for managing network organizations*

Davidow comes up with the vision of 'virtualizing' enterprise structures [5]. This idea established the network paradigm in organization theory and hence the resulting coordination patterns. Yet, most works in this field are characterized by a rather programmatic nature and thus they are difficult to operate. Inter-organizational operations in value creation are postulated as success factor; still operational concepts in this field are rather limited to normative criteria for success, such as trust, rules of fairness or adequate technological support like a decent IT infrastructure [6]. A systemic management concept has not been developed yet. Most of the works from the research area of network management theories focus on the process of strategic planning and initiating cooperation as well as adequate conditions for realizing these. So far no network concept deals with an operative approach that supports synergetic value creation processes.

The description and analysis of existing theories is either fairly theoretical or rather abstract and thus only useful for practice to a limited extent. Most theories do not pay enough attention to the special character of non-guided networks [7].

Still these concepts offer a basis for coordinating networks by means of implicit guidance impulses so that they have an impact on operationalizing the stated theories and creating a set of rules useful for the guidance of networks.

C. *Systems theory and managerial dynamics*

The systemic perspective of this work is derived from systems theory which deals with the elements, structure and architecture of systems. Systems theory aims at designing organizational concepts and principles in the context of various systems, type- and complexity-wise [8]. The

examination of structural, functional and hierarchical systems also refers to aspects of behavior and dependencies within the regarded system.

Because of the complexity of production networks, it is essential to take various types of systems respectively perspectives into account. Different theories can be allocated to various types of systems, thereby illuminating aspects which are relevant for this work.

The 'Living Systems Theory' refers to roles, functions and levels of living systems ([9],[10]). The theory of social systems tackles the interaction of living objects embedded in a social fabric. Cybernetics studies the guiding and control of systems. The probably most familiar approach is the so-called 'Management by Objectives' which realizes a regulation of a system by previously setting objectives [11].

Beer's cybernetics concept focuses on the operationalization of cognition relating to the guidance and regulation of complex systems which can be applied to the design and guidance of socio-technical organizations [12]. An essential principle can be seen in the postulation that a control unit always needs to be part of the system itself. The control unit, spread over the whole system structure, is not forced into the system. This requirement conforms to the logic of corporate networks which are a set of subsystems each of them having its own objectives.

System-oriented management concepts are based on the cognition of systems theory and cybernetics. However, the focus is broadened by extending it from economic perspectives within an enterprise to a system's perspective, taking the system enterprise - environment into account which complies with the perspective of this work. Ulrich's fundamental works serve as a basis for describing a system and the function of guiding these.

The cognition of systems theory and cybernetics provides a basis for this work and the combination of these in the context of systemic management will be a major objective.

D. *Complexity management*

'Management in highly dynamic environments needs to address the increasing complexity of industrial networked structures'. Coping with complexity¹ is a major task of management. The approach of optimum variety serves as general, constituting formal principle of an organization. Referring to Ashby's work, the optimum variety approach implies that a system can only survive if its guidance variety respectively complexity is as distinct as the complexity or rather variety of the environment surrounding the system [13].

An important approach in this context can be seen in the scale invariance concept which states that the structure of complex systems is independent from size [14]. Closely linked with this concept is the principle of recurrence which indicates that a system, consisting of subsystems, is marked by an identical structure on each level and therefore each level itself is able to exist independently of the other levels.

The field of complexity management comprises the management of internal or external complexity drivers to such an extent that successful guidance of an operation is possible.

The concept of corporate fitness adopts Ashby's logic to the organization of enterprises [15]. According to that a situational, general optimum has to be pursued by means of creating favorable conditions for self-organization, spanning between bureaucracy and chaos [16].

Thus the regulation of a system by means of affecting the environment's complexity should constitute a central approach in solving the problem.

E. Self-Organization and emergence

A concept seeming appropriate to the initial problem situation is that of spontaneous order [17]. Order is understood as the non-consciously shaped result of a development process marked by individuals adopting their behavior to the environment.

Focussing inter-organizational levels as well as production systems, Ueda deals with self-organization and emergence phenomena [18]. Emergence describes the development of global behavior resulting from local interaction while being influenced by the environment [19]. In return the global behavior affects the individuals' objectives and behavior.

The existing theories in the field of self-organization and emergence generally base on the findings of systems theory and offer descriptive and explanatory models. These models refer to phenomena observable in self-organized systems which cannot be derived deterministically from the individuals' behavior.

Despite their disregard of socio-technical systems these theories serve as a frame of reference in this work.

F. Organization-theoretical management approaches

In addition to the aforementioned theories scientific foundation can be seen in the situational approach, stemming from the wide field of managerial organization theory.

This approach is based on the premise that an effective and efficient organization design depends on specific and situational conditions. Internal aspects are integrated into the design of an organisation in the form of specific success determinants for the value creation chain. Thus production processes demand other guidance and control instruments than development or innovation processes.

Further external aspects such as industry-specific characteristics, cultural aspects or legal restrictions, are integrated into the development of organizational concepts ([20],[21]).

III. NEED FOR ACTION

Pointing out the deficits of current research on network organization, it becomes evident that the aim of this work has to be the derivation and development of a universally valid system of rules supporting the guidance of cooperative value creation in development and production networks.

In contrast to existing approaches in theory and practice this work intends to present a rule-based, implicit guidance

concept which functions as a framework ensuring the protection of interests of all network parties in the sense of a network optimum.

The rule-based, implicit guidance of the autonomous, polycentric network enterprises shall enable the realization of potentials of self-organization in the form of high agility and adaptivity. At the same time the new network organization has to guarantee a high degree of guidance and hence efficiency in order to solve the aforementioned contradicting challenge.

With respect to the enforcement of regulation, mechanisms and principles shall be analysed which are effective in decentral organizations consisting of economically and judicially independent individuals and hence are not based on traditional hierarchical directions and sanctions such as exemption.

In this connection a special focus is put on the analysis of incentive schemes as well as logics of accounting for services which are supposed to make regulation adherence reasonable with respect to the enterprises' objectives.

For the purpose of an effective and efficient concept eliminating the above-mentioned deficits, two conditions have to be set.

The network manager who is usually an active part of the value creation process acts as a coordinator and hence guides the consolidation of the individual efforts into a coordinated system. The manager's task is defined by harmonizing the network enterprises' activities and thereby trying to channel the different identities and hence target systems.

Rule-based exchange processes, e.g. transactions of services, are based on rule-based negotiations. These result from the economic and judicial independence of the network enterprises. The coordination is undertaken by means of a dynamic set of regulations (rules in the sense of code of behavior). By doing so an actively organized negotiation system evolves that is characterized by market conditions due to universal rules. Within the network a market environment develops in which the strongly adopted levels and matters of service are linked to specific service conditions in a way that supports the achievement of the network optimum.

The set of rules helps in suppressing short-termed opportunity actions of individual network partners. Thus the network manager creates a framework, henceforth mentioned as context, within which a spontaneous, self-organizing order is created which aims at leading to the overall network optimum [17].

This management approach conforms to the systemic-evolutionary category of management approaches. The context can be interpreted as a meta-level which is shaped by the management impulses of the network coordinator. Hence changes in the context lead to an adoption of the new framework on the enterprises' side. In terms of Ashby's logic a network adopts its inner complexity, e.g., structure and processes, to the changed outer complexity, for instance market situation [13]. The network manager captures the extent of compliance with the regulations as well as the absorbed results of the overall network, e.g. in the form of a product. The effectiveness of the regulations, i.e. the negotiation result, as perceived by the network manager, is

accounted for in the subsequent managing activities of the manager.

Both the transformation of the rules making up the context and the back coupling of the results to the manager is done by processing them through a transformation level. This does not only lead to a change in matters but also to a time delay concerning the operative transformation. In this context the transformation level is not only defined by the network-inherent characteristics but also by industry-specific principles as well as by means of the rivalry situation.

IV. STRUCTURAL AND PROCESS DESIGN OF PRODUCTION NETWORKS

In recent years cooperation activities between companies have increased enormously. The cooperation can reach different status and scale for participation partners, depending on the common motivation. The target declarations could be seen in product enlargement, risk reducing, cost sharing, resource sharing or better treatment of complexity for example.[22]

The following two sections give a short overview of the theoretical foundations of network theory.

A. Structural Design

There exist various forms of networks. However, all of them can be defined by constituting criteria such as coordination, duration of cooperation, distribution of power and the organization of competencies and capacities between the network partners.

Coordination is understood as the alignment of the individual activities with respect to the overall network aim. This alignment results in the various forms of network organization which can be found in industrial networks: cooperative, competitive, hierarchical and negotiation-based [23].

The duration of cooperation simply defines whether a network is set up for a short-term period which often happens with reference to a specific project or for a long-term period which might be the case for initially motivated development networks.

The organization of capacities and competencies within a network needs to be done for the complete network organization and requires an intense exchange of information between all partners [24].

B. Process Design

Basically, networks are designed in order to transform the win-lose-situation - a consequence of increased competition - into a win-win-situation [25]. The network design can be divided into three stages. During the first phase decisions have to be made answering the basic questions whether cooperation should be initialised, at which position in the process chain it is useful and which aims define the intended cooperation. The second phase represents the selection of the partners. This selection should be made according to a strategic and cultural

fit with respect to the network. Finally, the proposed network configuration has to be arranged in line with all participants.

In doing so, it has to be taken into account that a too rigid construction can be a hindrance in dynamic markets and therefore one has to operate quite flexible [26]. Figure 2 summarizes the process of network initiation.

Process-driven network organisations are designed along the supply chain; core competences are combined in order to gain competitive advantages [27].

In literature, process-driven production networks are understood as supply chains characterized by a cross company control and planning of goods-, material- and information flows along the supply chain. An order-related view relating to resources and the work system via network-wide monitoring can enable a comprehensive order management as well as transparency. Beside a high planning security a distinctive adaption- and networking skill is necessary. Often, the companies' behaviour might be harmful for the network welfare since the individual companies unveil their interests and aims just rarely.

The product development and processing time can be reduced immensely via synergy effects which might lead to sustainable competitive advantages [24].

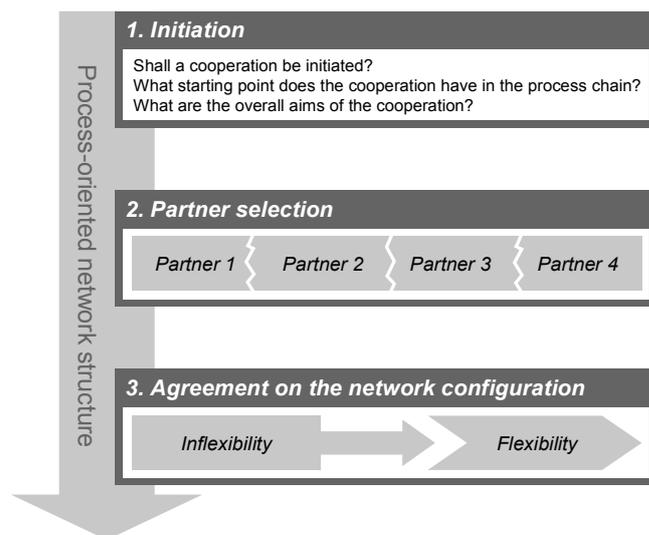


Fig. 2. Network initiation

V. DESIGN OF A RULE-BASED NETWORK ORGANIZATION

The following two sections point out a structural and process-oriented design for the suggested rule-based network.

A. Structural design in a rule-based network

For the purpose of an effective and efficient concept eliminating the above-mentioned deficits, several conditions have to be set.

The network manager who is usually an active part of the value creation process acts as a coordinator and hence guides the consolidation of the individual efforts into a coordinated system [28]. The manager's task is defined by harmonizing the network enterprises' activities and thereby trying to channel the different identities and hence target systems into the direction of the overall network aim. He is also the instance who is responsible of integrating all information which is relevant for the production process. [29] A high extent of identification on part of the network manager can be achieved on the one hand by the fact that he is directly connected to the outer perception of the network results and on the other hand, he is rewarded with a premium for acting as a provider towards the clients. The premium can be justified because every partner profits from the coordinated network activities.

The duration of the cooperation in a rule-based network depends on the availability of resources. If they exist sufficiently a long-term cooperation is favourable because trust and a well-balanced network can only arise in the course of time. However, short-term cooperation is often determined by a specific project when the client postulates a deadline.

The coordination is undertaken by means of a dynamic set of regulations which are understood as a code of behaviour or a value system. By doing so an actively organized negotiation system evolves that is characterized by market conditions due to universal rules.

The set of rules helps in suppressing short-termed opportunity actions of individual network partners. Thus the network manager creates a framework, henceforth mentioned as context, within which a spontaneous, self-organizing order is created which aims at leading to the overall network optimum [17].

B. Process design in a rule-based network

In the following section, the phases of network design which have been defined before are presented for a rule-based network. The need to create a rule-based production network deduces from the research fields' motivation. In order to live up to the complexity of the requested technical systems, it is necessary to operate in networks which are both efficient and effective. Therefore, it is essential to neutralise the target conflict between guidance and flexibility. Ideally the network actors jointly source their resources so that they benefit from reduced purchasing resources. During the phase of partner selection it is essential to pay enough attention so that a fundamental, strategic and also cultural fit is ensured. The

agreement about the configuration of such a network is in parts self-organized because only those partners who are able to reach an economic benefit join a network. This forms the networks' normative framework.

For a successful operating network a cross-company, which means network-wide, process control and planning is necessary. Concerning the phase of initiation for a rule-based production network it can be said that the network should include all stages of production.

In a rule-based network the network manager is entitled to this task. Because of his active role within the network, he has better knowledge about the processes in the network as an external network manager for example. If the manager is to influence control and planning in the network, he must have abilities and rights that allow him the network-wide control and planning. More explicitly, in his central role he needs to be supported by an information system for all the relevant information concerning process monitoring and securing. This implies that the network manager as an active part of the network must be familiar with knowledge concerning the various phases of production. Ideally, the network managers' company has a highly vertical range of manufacture, so that he has a wide knowledge about integrated production processes. Furthermore, the network manager is responsible for the supervisory control of the material flow and the flow of goods which he coordinates on the basis of an appropriate information system.

Despite the fact that the network manager controls and coordinates the processes mentioned above, it is necessary for a rule-based network that the network partners' production planning and –control is organised decentralised which means that this is done individually by each partner. Otherwise the trade-off between flexibility and span-of-control will remain. Prior to the production planning and control, an allocation of the tasks between the network partners is necessary.

For reasons of minimizing the complexity regarding the modelling, the network is described with a minimal number of actors. The cooperation-partners A and B form the triad's constitutive characteristics as well as the network manager who plays an active part in the network himself. Figure 3 shows a generic example of the triad and the relations between the actors.

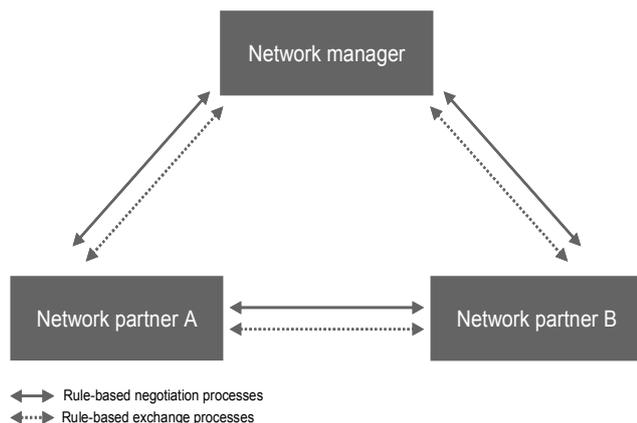


Fig. 3. An exemplary network triad

VI. MANAGEMENT BY RULES

Rules are universal and durable restrictions influencing individual and collective acting. Thereby the target is to structure individual and collective acting. A rule-based framework ensures effective and efficient collaboration in standard decision making procedures.

Avadikyan et al. defined rules as follows: “A rule is conceived to solve a problem of allocation or creation of resources, it serves as a main function which can be of a cognitive, incentive or coordination nature, it is ambivalent, i.e. it entails side functions in addition to the main one.” [30]

Within this paper rules can be understood as tools to influence individual and collective acting in standard decision-making procedures and furthermore, due to its properties of formal and informal codification degree, as a suitable instrument for the steering of individual and especially collective behaviour within a specific frame. This specific frame can be an alliance or a company network.

The managing aspect is therefore to develop and to enforce rules between the cooperating network companies. Thus, to offer an advanced understanding for rules the next chapter deals with the characteristics of rules which are characterised by the functions coordination, cognition and constraints.

A. Coordination, cognition and constraints as influencing factors

When discussing rules, first of all there is the question why actors should respect rules and why it is rational to follow them. This question will be discussed in the context of the three functions coordination, cognition and constraints. [30]

Coordination, cognition and constraints, every rule or set of rules aims at least at one of these properties. They are not independent; moreover, they co-exist with a high coherence within efficient working organizations. The coordination

objective is the one which every organization emphasizes. It is crucial to bring actors together in order to accomplish the common goal. This is necessary because organizations are systems with agents of different interests and diverse knowledge. [31]

To gain more efficiency these asymmetries of information have to be controlled and thus the organization has to be coordinated [31]. This can practically be achieved through meetings as formal face-to-face interaction or intensive communication supported by information media [32]. Furthermore, the coordination aim provides coherence and compatibility to every single action. Coordination is always associated with a certain scale of control and is dependent on the structure of the relation [33]. For instance, in a classical hierarchical structure, such as a supplier - manufacturer relation the coordination is organized vertically. Contrary, coordination patterns are organized horizontally in relations with balanced power agreements. Project groups or balanced alliances are examples for balanced power agreements.

The second major role of rules is the constraining objective. In an organization governance of behaviour and emergence of motivation are daily business. Because of deviant interests actors are steered by a reward system such as bonus arrangements or sanction mechanisms to generate incentives [33]. The set-up phase is a typical example where an enhanced tendency for opportunistic behaviour occurs which is caused by the lack of trust. This lack of trust can be covered by suitable rules which promote the constraining and motivating functions.

The third objective addresses the cognitive objective. The cognitive function stresses the organizational learning process. To be exact, it describes the crucial processes of maintaining, transferring and developing of knowledge and know-how – the organization is seen as processor of knowledge. Literature differs between several kinds of learning for instance by the codification of knowledge such as formal or informal knowledge [34] or by the configuration of learning participants such as individuals or collectives and by the source of knowledge such as external or internal sources. However, focusing on inter-organizational relationships it can be separated between interactive and unilateral learning. Interactive learning is the cooperative process of two or more actors working together on one project or task while learning with the partner. The learning output is characterized by tacit or collected and rehashed knowledge. Meanwhile the unilateral learning process represents a unidirectional learning behaviour from a partner, about his abilities and his competencies. [35]

However, the way of learning is central for the cooperation process. The success of controlling the learning process and thus the cognitive objective is crucial for the collaboration success and will influence the actors in their behaviour enormously. [35]

Rules are suggested as steering tool because they can be formulated in a certain scale between informal and formal. Corporations or networks are always changing in an evolutionary way while adapting the structure and processes to aim the optimal market demands. Therefore procedures run through certain stages of development and thus, rules first are developed tacitly and later gain in importance and finally, will be formulated in a codebook, contract or agreement. [31] Contrary to promote a more flexible negotiation situation the formal status of rules can be suspended and similar tacit rules can be established.

Therefore, it is necessary to distinguish between contract-based networks and rule-based networks. Interorganizational relationships are typically based on contracts which are formal agreements. Contractual-frameworks establish network configurations with a very specific disposition of the network actors and establish a distinctive basis for sanction-mechanism.

VII. CONCLUSION AND OUTLOOK

The need to particularize these concepts is a consequence of the design and process structure of a rule-based production network. For the process-oriented organization this is made by the analysis of management content for which the dimensions "design, control and development" are set in context to the considered triad architecture. Thereby, the relevance of each dimension within the corresponding network unit will be determined.

After the clarification of the management contents, it is necessary to structure these contents by normative, strategic and operative content. Finally, those positions and levels that carry a potential for conflicts of interest and information asymmetry are being determined. For these positions and levels a link to regulations must exist with the aim to prevent opportunistic behaviour.

The regulations and their effect for the self-organisation in context of the triad production network should be developed according to the cause-and-effect-relation in the triad. These relations determine the logic and content of the defined set of rules. Therefore, the rule dimensions have to be deduced as well as a conception which serves as a basis for the rules. By means of this kind of network companies are able to concentrate as well diversify on a strategic level as opposed to the classic organizational view. [36]

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