Field theory revisited – Explaining the development of an organizational network by dynamic simulation of psychological field[1]

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ABSTRACT

The following contribution is about a method, which uses modelling and simulation in the context of action research. Long and complex projects shall be supported with well-founded dynamic models and simulation of possible developments in the project. The method is described exemplarily in the context of a major research project developing a network of competences. It's goal is to design a distribution platform for current and innovative qualification programs and services in the car industry, such as on-the-job tutorials for machine operatives or courses on new body part materials. The method of supporting the project by modelling and simulation based on qualitative data is described, exemplary results are discussed and hints for further research are given.

Keywords

Innovation networks – simulation – motivation – cooperation – complexity

1 Introduction

1.1 Aim of the research

The following contribution is about a method, which uses modelling and simulation in the context of action research. Long and complex projects shall be supported with well-founded dynamic models and simulation of possible developments in the project. The method is described exemplarily in the context of a major research project. It's goal is to design a distribution platform for current and innovative qualification programs and services in the car industry, such as on-the-job tutorials for machine operatives or courses on new body part materials. This information shall be available for learners in small and medium sized enterprises, which are connected in a value chain with large advanced car manufacturers. The practical impact is a quicker distribution of knowledge about new manufacturing methods and tools to the local suppliers by a so called network of competences. This network shall work and grow autonomously after a starting period. The core concept is a market place. All kinds of education services and tools which are useful for the goal of the network shall be distributed through this market place with guaranteed high quality. The development of real as well as virtual market places varies extremely between dynamics like early ebay or a rather stabile business like those on the Ponte Veccio in Florence. The goal of the specific research described in this contribution is to develop a dynamic simulation model for this market place. The purpose of modeling and simulation is to find out which variables must be triggered so that the market place develops positively, and how the motives of participating stakeholders must interact for a dynamic development. The market place and its content should grow, comprise actual and useful knowledge for the learners and enterprises, and it should be to a high didactical standard. The dynamic and interdependent development of the market place organization and the motivation of the market place participants and other stakeholders play a central role in this process. Their interaction has a strong influence on market place quality.

The contribution explains how modelling and simulation can be used here as action research and project management tool for several purposes: They help to identify possible helping and hindering

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forces for a positive development and to analyze their influence. Simulation shall generate hints for measures supporting the positive development of the market place and helps to assess long term and side effects of possible decisions and strategies in a specific project. This simulation method will be especially suitable for modelling and simulation in projects with few participants and singular conditions and tasks. In long term projects is it not completely clear from the beginning which aspects become important because they depend from a framework of economical, technical and psychological variables, which can change over years. Therefore the classical idea to define a set of variables and to measure them through the whole project often not works for finding out relevant factors in long term change and innovation projects. On the other hand many qualitative data can be collected in such projects. The core idea of the method is to develop a model from a dynamic qualitative data base and to use this information for the continuous optimization of a modelling and simulation process accompanying the project. The possible simulation results have heuristic character. They describe the dependencies between activities and consequences for possible configurations of the network, for different decisions about the structure of the network and for different external influences. Simulations of this type broaden the knowledge about possible alternatives in proceeding during a process and provide for a better understanding of possible side-effects and dynamic long-term developments (Riedel et al., 2009; Dörner, 1996). The main steps of this method are in our case:

- Developing a basic structure of the theoretical state of the art,
- description of the rules for the system's dynamics based on simple and updated assumptions of classical field theory (Lewin, 1947),
- investigation of the specific motivation and mental models of the agents,
- development and application of a method to derive variables and parameters for the concrete project,
- simulations of possible developments of the specific innovation or change process under different possible conditions.

The application will be described for an exemplary feasibility study for the education services network. So the theoretical background is related to competence networks, market places and psychological factors influencing their development. Steps of this method are applied in the design processes of the market place for educational services. It will be shown exemplarily how this works for two core problems for a successful market place solution.

1.2 State of the art – old theories for new solutions

The first step is to propose a structure for the simulation of a specific process. To do this in our case, actual research on basic assumptions about structure and dynamics in competence networks must be checked. There exists research about the concept of 'networks of competence' and descriptions of existing projects and literature on success factors of networks with similar goals especially in the field of R & D. Most of the empirical research is about success factors in general either based on questionnaires (Olsen et al., 2014; Schøtt & Jensen, 2014; Gebreeyesus & Mohnen, 2013) or qualitative single case studies (Li et al., 2010; Liu et al., 2015; Häntsch & Huchzermeier, 2016; Chung & Leung, 2005). Beside the economical, technical and infrastructural quality the psychological success factors described here are trust (Gulati, 1995), and relationship quality (Borgatti et al., 2009). According to research about cooperation in complex long term projects mental models are useful which base on core concepts built up on shared mental models (Espinosa et al., 2001) and specific methods to generate them in specific methodological processes (Schönwandt et al., 2009). Theories about the structure of organisational networks make assumptions about different types of single persons, groups and organisations. They are promoting such projects in different roles as stakeholders with different interests (e.g., Sharma & Kearins, 2011; Dähne & Heisig, 2019). There exist core assumptions in most of these models: The networks are promoted by *stakeholders* following their specific interests. They can take certain *roles* and promote networks in a different way (Dähne et al., 2019). Cognitive, emotional and economical *ressources* of the stakeholders influence their success. These factors change during the project, motivated by changes in organization, by critical incidents, by own and other stakeholders' activities and their results. There exist important psychological influences on the development (commitment, trust, shared mental models) of a change or innovation process.

Besides these assumptions on network structures until now there exist no elaborated models on the process of network development which describe the role of dynamic psychological factors for the growth and success of networks. Also there are no proposals what to do to support the motivation of the stakeholders throughout the process. The psychological theories about the motivating effects of objects and occurrences are based mainly on the ideas of Kurt Lewin. Therefore the proposed simulation of the developments of incentives is based upon classical work of Lewin (1969), Gibson (1977) and Norman (1988) and their concept of affordance or „Aufforderungscharakter" (Lewin, 1969). Norman

(1999) distinguishes between objective affordances of an object and subjective affordances which work as an incentive for a specific person with a specific goal in a specific situation. For the design of the market place and other organizations we propose to define objective affordances as features of explicit objects and formal rules for activities to influence an activity or emotion to reach a sustainable development of the organization. The specific affordance for the stakeholder describes the intensity and quality of the incentive for a specific action in a specific moment t_x. Moreover, the field theory or topological psychology provides necessary basic assumptions for modelling dynamic processes: Lewin (1947) derived the basic assumptions of his model of change management dynamics directly from the mathematics of topology. These mathematical models later have been developed to modern decision theory, which relates to single decisions, but they do not relate anymore to the description of greater parts of reality as a psychological field.

2 Hypotheses

The main assumption of this contribution is that an organizational structure like the marketplace for educational services can be simulated in a dynamic manner following the classical principles of field theory. This can be done as action research for single projects of organizations based on qualitative data. For simulating the development and assessing the incentives of network solutions the affordance of every object or activity in such a network can be built as a set of variables. Each of them represents the subjective affordance for a specific stakeholder. A subjective affordance generates the incentive for activities of specific stakeholders in a certain moment.

Automatically, the network objects are dynamic, because affordances change depending on stakeholders' knowledge, their actual plans, emotional states, interests and the influence of other stakeholders. To find out in which way the whole network develops the interplay of this factors can be simulated based on empirical information about the stakeholders' psychological preconditions in a specific organizational and technical network solution.

3 Method

The design of the simulation model is described below. It allows retrieval of basic information for the simulation of possible effects and to assess the quality of possible solutions for the network design in the market place. These steps are described for this project. Examples of results from applying this method in the course of the project are shown below (for more details see Wieczorek et al., 2018).

3.1 Identification of incentives and obstacles resulting from stakeholder interests

The network of competences started with a preliminary list of the project partners. They have formulated a basic and more or less specific interest for the project. So the starting set of market place agents are: an original equipment manufacturer (OEM), a tier one supplier, a commercial education service provider, a state university, an association of car industry suppliers, and a company developing IT-solutions for on-the-job-training. At the beginning of the project their roles as stakeholders are not fixed. For example, the first level supplier can have the interest to buy certain content and education services, but it also has the possibility to advertise content and services on the network like to let their car workshop to trainees of other companies or education service providers. So semi-structured qualitative interviews have been conducted to collect the following information from each project partner:

- What are success factors for the described market place, which features are necessary?
- Which incentives lead to an active participation in the market place?
- Which features need products to be advertised successfully on the market place?
- Which obstacles exist?
- Which roles must exist in this network?
- Which tasks are related to these roles
- How do successful owners of a role fulfill their tasks?
- Which are possible own roles and activities in the network?
- Which own resources exist for this role?
- Who are other possible participants for roles defined in the network?
- Which possible outcome has these activities for other network partners?

3.2 Integration into a first structural model

The results of the interviews were categorized along the following general structure of networks derived from the theoretical state of the art: First of all *roles* exist in the network. For these roles *tasks* and necessary *resources* to manage the role successfully can be derived from the interview data. Also *stakeholders* (possible owners of roles), *subjective affordances* for single stakeholders and *objective affordances* to for an owner of the role can be extracted. Also other *features* were described in the interviews. Stakeholders are the agents in this system. They are described by their *goals*

and *resources* for one or more possible roles. *Products* and their *features* is the third type of element. All three elements are connected by different types of *relations* (A is dependent on B, A is a realization of B, A is a part of B, A does something to B).

The empirical results are entered in a database and diagramed in a formal system consisting of these elements and relations. Then a structural analysis is conducted based on the following type of matches:

- Participants' resources and the necessary role resources.
- Participants' goals, their specific affordances and role tasks.
- Product features and the participants' resources providing them.
- Participants' goals and product incentives.

This analysis can be done by hand or automatically with standard database queries or a specific deductive data base (Seipel et al., 2016). The method of deriving unified models of such networks out of qualitative unstandardized data from documents and interviews is described in Wieczorek (2020): This methodological approach can be used as a specification for a software which allows to extract valid basic models for simulation for each unique project or network. As a result of this analysis the features are listed which can be used as parameters and variables for the dynamic simulation of the market place.

3.3 Developing dynamic simulation models

These variables and parameters are integrated in a model simulating market place dynamics. Based on the structural model variables for dynamic simulation can be selected out of the feature list. At first this can be done on a qualitative level in a matrix of influence (Vester, 2012). It describes the interaction in both directions between all direct combinations of two variables in the system. A simple form of description, which can be derived from the qualitative data has four categories:

- Positive (more of A leads to more of B, less of A leads to less of B),
- negative (more of A leads to less of B, less A leads to more of B),
- unknown, but existent,
- non existent.

In a first rough-and-dirty modelling procedure the matrix is filled with these categories. The reasons for choosing one of these four possible relations are described for each combination. If plausible or empirically founded mathematical relations exist, this first estimation can be replaced by mathematical equations. This allows a dynamic modelling of the market-place structure. This step can be realized with specific editors. In this case the freeware simulation editor insight-maker® (Fortmann-Roe, 2015) has been used which allows an iterative alignment of the market place model. Criteria for assessing the quality and progress of this process are described in Starker & von der Weth (2011) and von der Weth et al. (2016): Logical consistency, non-triviality, plausibility, concreteness.

The iteration stops when logical consistency is reached and non-triviality of possible prognoses is given. The plausibility and concreteness of simulation results must be assessed by experts in several iterations of model development. Concerning non-triviality, the simulation model allows identification of possible developments which have not been known before.

3.4 Identifying critical processes for important network solutions

The model can be adapted for different questions which arise in the process of the project.

In the course of the project the knowledge about market place structures can change as well as the knowledge about single elements or specific relations. It can be useful to integrate this knowledge into the existing models.

There also exist possible reasons coming from the involvement of action research projects in reality. If there is a vital interest of stakeholders for other solutions it is pragmatic to create them. E.g. it can be useful to analyze system configurations with additional stakeholders or products which do not exist until now or to create sub-models for specific problems or decisions. In most cases these sub-models are simplified.

3.5 Simulation and analysis

Depending on the quality of the model different analyses can be conducted. Already on the qualitative level of the matrix of influence critical factors, leverage factors and inert factors can be identified. Critical factors influence most other variables simultaneously. There until now exits no convention about the number or percentage of variables in research, so this has to be found in the specific research process. Critical factors (among others) can cause major disturbances in a system and they therefore have to be watched carefully. Critical factors which can be influenced directly by stakeholders' activities are called leverage factors. Measures influencing these factors have strong but difficult to control effects. Inert factors are variables which are influenced by many others. Again there is no convention for „many", it has to be

defined in the research process. On the qualitative stage possible dynamics in systems can be identified: Two connected positive relations can lead to a self-reinforcing feedback loop. (Motivation for creating high quality products leads to happy customers and vice versa). This suggests any developments which cause a decrease in product quality would have to be monitored carefully as a source of risk which causes a reversal of the positive feedback loop. A positive relation connected to a negative one can lead to a stabile equilibrium. The classical economical relation of supply and demand is a system of this type.

The dynamic simulation allows more detailed analysis of these processes by identifying more concretely the course of processes and testing alternative developments depending on the possible different values for chosen variables. Main purpose for this is testing scenarios. These scenarios are fictious network configurations, values for goals, resources of the stakeholders and hypothetical rules for system dynamics. These scenarios can be figured out during the development process for several reasons: Best case and worst case scenarios, testing the marketplace's reaction on possible critical incidents and crises. Is there consensus about the hypothetical set of variables and functions the result of simulation is exact. So scenarios for the effects of decisions can be developed, the role of critical factors can be described in a more concrete way, and the prerequisites of best and worst case scenarios can be analyzed more carefully.

4 Example results of the feasibility study

4.1 Development of a structural model

Interviews with stakeholders have been conducted from January to June 2016 (n = 12). The range for the duration was from 60 to 120 minutes. The full text interviews were recorded and transcribed. The analysis of the interviews followed fixed rules described in a handbook and started with initial assumptions, derived from theoretical analysis. The elements of the structural model, which has been derived from these data are described in table 1. New elements identified in the interviews are marked in bold.

Table 1: Elements of the structural model. New elements are marked in bold.

Types of elements	*Elements*
Role	Market place provider
	Educational products provider
	Service providers Customer for educational products
	Learner
Stakeholder	**Commercial education provider**
	Software Developer
	Universities
	Public Organization / Job Agency
	Trade Associations / Chambers of Commerce
	OEM
	Suppliers
	Machinery manufacturer
Product	Market place
	Catalogue of user rules
	Digital ressources
	Educational products
	Information about Request

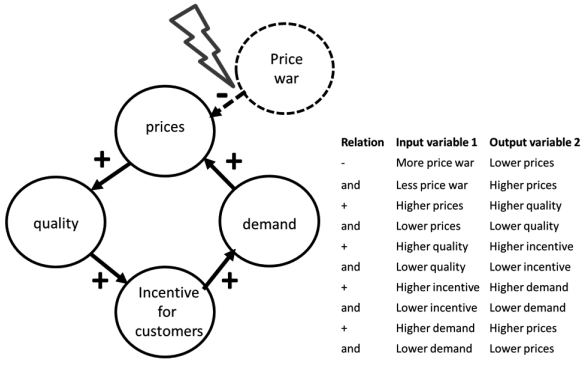
An example for results of the qualitative data analysis based on the structural model is a possible mismatch between the affordances for a market place provider and the aim of the network. A marketplace provider with main focus on economic success must have the interest to generate a maximum of participants. These can generate a conflict with the quality goals of other stakeholders of the network because the number of possible participants is generally limited. There must be other reasons to take part than mere economic success. Possible owners with such features exist and have been interviewed. Table 2 shows that for the stakeholder „association of car suppliers" matching interests exist and can be taken into account during the design of the affordances of the organizational network solution.

Table 2: Match between role (market place provider) and stakeholder (car suppliers association).

Elements	*Features*
Role Market Place Provider	Tasks Monitoring the rules of the market place and the network Publishing concrete requests Necessary resources Webspace Staff Other features Neutrality (no conflicting interests with other participants)
Stakeholder Association	Goals Similar to the goals of the whole project, e.g. high quality of the educational products for the association members Existing Resources Associates as possible customers Can finance the marketplace from other resources Digital equipment Other features Certification Digital ressources
Product	Tasks Transfer of information Other features Open for all participants

4.2 Identification of possible developments and risks by simulation studies

An example result for the dynamic simulation related to this problem is a local model of a specific dynamic development of the quality of the offered educational services and tools. It shows processes which can arise when the provider designs a network following some classical principles of very successful market place ebay by publishing prices in the internet and leaving the quality assessment to the users. An assumption of the scenario is, that the number of potential customers is limited because of the specific purpose of the market place. The priority of quality is high, because the car suppliers themselves have to follow strict quality rules. The scenario in figure 1 shows basic assumptions of the simulation model. The dynamic simulation of this process allows analysis of the details of possible risks. There is a self-reinforcing process which can develop, when the market place has too many participants with similar educational products and one of them starts reducing prices.



Relation	Input variable 1	Output variable 2
-	More price war	Lower prices
and	Less price war	Higher prices
+	Higher prices	Higher quality
and	Lower prices	Lower quality
+	Higher quality	Higher incentive
and	Lower quality	Lower incentive
+	Higher incentive	Higher demand
and	Lower incentive	Lower demand
+	Higher demand	Higher prices
and	Lower demand	Lower prices

Figure 1: Self-reinforcing feedback-loop. Without price war the system develops in a positive way. A price war leads to a self-reinforcing decrease of the market.

The simulation result in figure 2 shows that even a short price war can lead to an irreversible negative development. This process can be avoided with a high probability, if the owner of the role is the car suppliers association because their main interest

is to provide high and certificated quality for their members. Another part of the solution is that prices are not included in the first description of the offer and detailed pricing takes place after first contact between education product provider and customer.

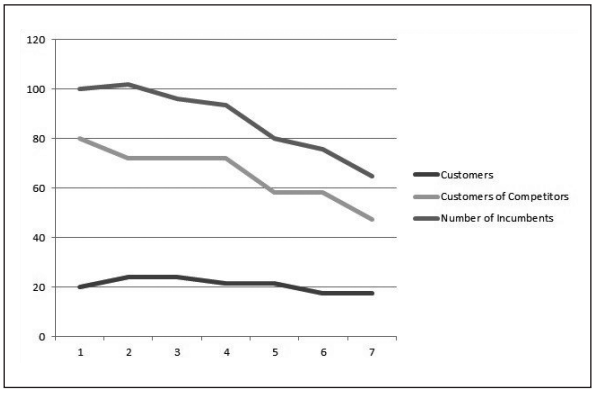


Figure 2: Dynamic simulation of the price war scenario. Long term effects of a price war at t2 and t3.

5 Discussion

5. 1 Liquid research

The method described here uses modelling and simulation as a tool to support complex projects. The fit of such models developed step by step during a process of action research in a practical project cannot be tested in one single investigation, like in an experiment. It also influences the course of activities of the project. The structural model and task-specific dynamic simulation models develop in an incremental process during the project. Therefore the authors propose to call this process „liquid research". Although a useful overall prognosis for the complex project concerning the fulfillment of its goals is not possible in many cases, the quality of models developed this way can be tested: Besides developing a common sense approach for finding testing procedures for the formal criteria of consistency, non-triviality, plausibility, and concreteness, it is also possible to improve the anticipation of consequences of activities step by step during the process. Prognoses about what will happen should improve during the process, if the model improves iteration by iteration.

5.2 Limitations

The method is suitable for a better understanding of socio-technical processes in specific projects. It is not capable of proving a general theory of socio-technical change. This can work by integrating such models from several projects. One can compare these models by conducting meta-analytical studies, but another way is also possible. Because the types of the elements have the same structure, it can be possible to combine them into an overall structural model in a common database with a broader validity for different processes. Besides practical requirements, there exist no rules when the development of a model is finished, and so a permanent process to develop an overall model can be started.

The problem of comparing quality standards for simulation models with classical statistical quality norms like alpha-level of 5 % is not solved until now. A lot of discussion about building quality rules for a „good result" has to be done. But this not an empirical study, it is a discussion about norms and their justification.

One practical problem at the moment is that modelling is very complicated process. The dynamics of projects can become very high. The retrieval of data for the model, the qualitative modelling and building dynamic models can be overtaken by reality. Then modelling of this type is not adequate for the practical purpose of the projects which are analyzed and supported in this way.

5.3 Future activities

State of the art and limitations show the way for the next steps. The tools for simulations of this type can be improved. They must be connected to each other and the models must become more dynamic. A new input should be processed immediately by software to automatically create an expanded model. There must also be a software solution for merging several models of this type. The software solutions should also have easy handling and should be based on standard products which are cheaper to use. Currently, a second project has started following these principles.

The second task is a better foundation of the epistemological background of simulation. Especially, a standard has to be created on how to assess models and simulation results.

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