Modelling dynamics in decision support systems

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Abstract

Decision support systems (DSS) play an important role in supporting scheduling tasks in industrial settings. In this paper, a special facet of DSS, respectively their development, implementation and usage in relation to user participation, is examined. The outlined research model proposes that different forms of user participation lead to different levels of model complexity. This complexity influences in turn such outcome variables like system performance, user satisfaction etc. The research model integrates several existing concepts from technology acceptance, planned behaviour, involvement and participation research as well as control theory. These theories are expanded by the dynamics of the modelling process. For the empirical analysis multiple case studies examining different cases of DSS development and implementation processes in different settings were conducted.

Keywords: decision support systems, modelling, user participation, usability

1. Introduction

Decision support systems are widely used in production planning. Over the last decades, the software has used increasingly the results from Operations Research, a field of applied mathematics that uses advanced modeling and solution capabilities. Especially in Advanced Planning Systems, techniques based on mathematical prorgramming have been implemented. Since the actual modeling of the business and operational processes needs to be conducted at a fairly detailed level, the development and implementation process increasingly is a process of modeling, making use of a toolbox of advanced optimization capabilities.

In this paper, we are interested to investigate this modeling process. Especially, we are interested in the interaction between the developer/modeler and the user. The user typically has a lot of domain and problem knowledge, but lacks the knowledge of the modeling tools and in many cases the abstraction capabilities necessary to do the modeling. For the developers, this is oftentimes the other way around.

2. Literature review

2.1. User participation and user involvement

User participation is considered to be critical for the quality and use of IT systems, [16]. A good overview and a meta-analysis about the effects of user participation on system success can be found for instance at [1].
First we have to define user participation and user involvement. User involvement is seen - especially in the MIS (and DSS) context - as a subjective psychological state of the individual user in terms of importance the user attaches to a given system [22]. Participation, on the opposite, is an observable behaviour respectively a behavioural engagement

[17].
Considering the existing research it can be subsumed that most of the studies done so far in the field of IT in general, MIS and DSS make a clear distinction between involvement and participation and refer to such outcome variables like user satisfaction and (perceived) benefits, see for instance [1][3][7][11][12][13][15][16][20][22]. In the numerous models input variables are usually user involvement, user self efficacy, user attitude, and user participation. Output variables are usually system usage, satisfaction, acceptance and system success. Task uncertainty, competence, qualification, and other characteristics of the situation, the system and the user serve as moderating variables.
Integrating the available research results it can be stated that we need to look at participation as well as to user involvement, that we need to distinguish between different stages of the development process, that we assume, in congruence with major findings, that user participation and user involvement have a direct significant impact on the attitudes toward the system, which in turn leads to system acceptance, and on user satisfaction and hat this relation depends on several variables like characteristics of the user, the system or the situation.

2.2. Technology acceptance

The performance and satisfaction resulting from the usage of an information system depend largely on the acceptance of the particular system respectively the technology. For the explanation of technology acceptance serves the Technology Acceptance Model (TAM) proposed by [1]. The TAM is based on intention models from social psychology, especially the theory of reasoned action (TRA). The TRA assumes (a) that behavioural intentions (BI) are prior to every behaviour and (b) that attitudes and subjective norms are decisive for the intentional behaviour [9]. The TAM is an adoption of the TRA, specifically tailored for modelling user acceptance of information systems [9]. The main concept underlying this model is that two constructs, the perceived usefulness and the perceived ease of use determine the attitudes toward using a certain technology and the behavioural intention to use [9].
Perceived usefulness (PU) is defined as the degree to which a person believes that using a particular system could enhance his or her job performance. Perceived ease of use (PEU) can be described as the degree to which a person believes that using a particular system is free of effort.
Empirical studies, spanning a wide range of different systems and user populations, have found perceived usefulness to be a stronger determinant of intention/usage than perceived ease of use [8]. A lot of empirical studies confirmed the stated relationships. Others extended the model in different ways, for instance by integrating communication aspects, general attitudes, culture, perceived developer responsiveness, experiences etc.
Interesting for the approach presented here is also the resent consideration of some dynamic behavior[8]. The result of this study was that only the user perceptions at the first state (early user reactions) and the usage behaviour at the previous state had significant relations to the usage behaviours at later states. This approach is also important for DSS. If the system and the inherent model isn't accepted by the user or leads to poor results a modification process is induced which causes high expenses and influences the overall profitability of the systems development and implementation project.

2.3. Control theory

Control theory has a close relationship to the research conducted in the field of participation. Participation in organisations implies, by definition, that workers enter into decision making and that workers thus exercise legitimate control [2]. Control itself is defined as the need to demonstrate ones competence, superiority and mastery over the environment [10].
Control plays a decisive role within the theory of planned behaviour (TPB). Within TPB, intention is determined by cognitive evaluations of the behaviour (i.e., attitudes), perceptions of social pressure (i.e., subjective norm), and perception of behavioural control (PBC) [18]. PBC specifies the likelihood of successful performance and will vary as a function of controllability toward performing behaviour. Controllability can be divided into an internal and external perspective [18]. Internal controllability describes the perception that someone has control over personal resources like skills, confidence, and the ability to perform a special behaviour. External controllability refers to the perception that a situation is relatively free from extrinsic influences.
Perceived control is also related to the level of participation within a design or decision making process [7][19]. They argue that in situations the more one actively participates in the event, the more control one has over the outcome. That implies that by allowing decision makers to manipulate decision variables and assumptions within a model and to observe the effects on predicted outcomes this should create confidence in the model and in the related outcome and should lead in the end to a higher level of perceived control [7].

2.4. Trust

Trust is seen as an attitude that an agent (or system) will help achieving an individual's goals in a situation characterized by uncertainty and vulnerability [21]. By guiding reliance, trust helps to overcome cognitive complexity. Concepts of trust are based in the behavioural intention theory. Trust can stem from either direct observations of the system behaviour (performance), an understanding of the underlying mechanisms (process), or the intended use of the system (purpose).

Design guidelines that should create a basis for trust in automation cover the transparency of performance, algorithms and purpose as well as the training of operators.

2.5. Complexity

In information processing complexity is a measure of the total number of properties transmitted by an object and detected by an observer. In physical systems complexity is a measure of the probability of the state vector of the system. Complexity can also be seen as the property of a system that hinders the description of the system or its behaviour. There are interrelations between complexity and performance based on cognitive limitations.

Complexity is in that way on the one hand the result of the modelling and design process and is on the other hand crucial for the performance of the resulting system.

When implementing APS systems, complexity increases as more details are modelled. A more detailed model enables creating schedules that have a smaller chance to be infeasible because some constraints in the process were overlooked. It also enables the scheduler to exercise more strict control, with less freedom on the shop floor to make scheduling or sequencing decisions.

To model detailed aspects of the production system in the APS, knowledge about these aspects is needed. The future end users of the APS are usually needed to provide such knowledge. When the detailed rules are modelled together with the future end users, the model will increase in complexity; however, for the end users the model will still be understandable. When detailed rules are modelled without participation of the end users, it will be much harder for the end users to understand the model and the underlying design decisions.

3. Development of a research model

Based on the conclusions of the literature review as wells as on own experiences and assumptions a research model was developed that is able to explain (dynamic) relations between participation, complexity and usage/ performance in modelling processes. The model is shown in Figure 1.

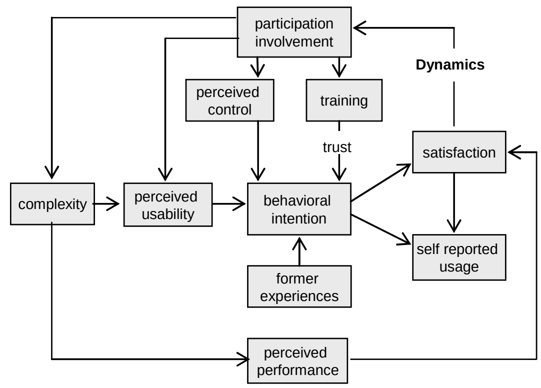

Fig. 1: Research model

When describing the participation of the later users when developing and implementing DSS there is a continuum between two poles: (1) involving the user in each stage of the development and implementation process starting when defining the project, analysing data etc. and (2) building the system without any user participation and then turning over the system to the user. We assume that user participation influences model complexity, i.e. if user participation is high then we expect the model complexity to be higher than if the user participation is low. In the first case the user will try to get every single exception to be considered in the model because then the model will represent the reality best. In the second case modellers will try to make some simplifications and to use standards because this will let the system work faster and it will make their work easier.

The propositions resp. assumptions, based on the developed theoretical model, that are to be investigated are

1. Linking user participation and the Technology Acceptance Model (TAM)
   a. Can the TAM explain behaviour also in situations with user participation?
   b. Do resp. how do different levels of user participation affect the behavioural intention to use a special system?
2. Do user participation and user involvement influence model complexity?
3. Model complexity and user satisfaction influence each other
   a. A higher degree of complexity leads to higher perceived usefulness but to poorer perceived ease of use and in the end to lower satisfaction.
   b. If satisfaction is low the level of participation will be increased (decreased) in order to increase (decrease) the level of model complexity, dependent if the initial model complexity was low (high).

The dynamic process is shown in figure 2.

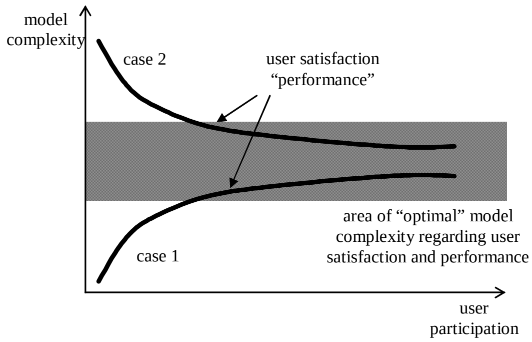

Fig. 2: Dynamic Process of Modelling

4. Research Methodology

The objective of the study was to detect relationships between user participation, model complexity and user satisfaction when implementing DSS for industrial scheduling, and possible dynamic processes until the model reaches a certain "accepted" stage. The scientific interest is mainly in description and explanation and a multiple case study comparing the findings in different settings should be the appropriate research strategy [23]. For the investigation a multiplicity of sources can be used, because there are a lot of people involved in and affected by a DSS development and implementation project.

Developing and implementing a DSS is a complex project. Its success depends on a variety of variables. Also the issue focused has a lot of relations to other factors, so the findings may be varying dependent on the situation. An analysis of quantitative data is not intended here because the underlying model would be so comprehensive that hardly all data could be captured. Also in prior research only particular aspects were examined.

The units of analysis are specific design and implementation processes for Decision Support Systems in industrial planning and scheduling. These processes are conducted within different enterprises from different industries and comprise different systems.

According to the proposed framework the whole project of implementing a DSS is divided into useful stages: development and implementation as well as all following stages of using and adjusting. For each stage the relevant variables are captured. Furthermore some situational factors should be captured in order to serve the comparability of the different case studies and also to exclude or possibly find some alternative explanations.

In order to be able to analyse all the relevant data a guideline for a semi-structured interview and also a questionnaire were developed consisting of scales for the following variables and constructs: perceived usefulness, perceived ease of use, system acceptance/ attitudes, behavioural intention, user participation, user involvement, perceived behavioural control (internal and external), user satisfaction, actual system use, model complexity (as comparison between the entities and relations in reality and those modelled in the system, furthermore restrictions and objective functions must be considered), model/system performance, and controlling variables.

5. Empirical findings

5.1 Experiences

The cases of four companies have been analysed. Company 1 employs appr. 360 people and produces moulds mainly for the automotive industry. The system was implemented very recently and has a moderate complexity. The design and implementation process was characterized by low participation in the conception and design phase but by moderate to high participation in the implementation phase. Employees feel high involvement and show high acceptance and high usage. The level of perceived control is also high.

Company 2 produces moulds and dies as well as moulded parts for the automotive, electronics and health care industry. There are appr. 300 employees. The complexity of the system is moderate to high in the mould production department and little to moderate in the parts production department.

In the mould production department which is characterized by one of a kind production there was a high level of participation in nearly all stages of the system design and implementation process. A high degree of acceptance, a high degree of usage and of satisfaction with the system could be observed.

In the part production department, which is serial or batch production there was a quite low participation in all stages of the system design and implementation process. People show a high level of involvement and also of acceptance. Although the level of usage as well as of perceived control is low.

Company 3 produces metal shaping dies for the automotive industry and employs appr. 160 people. The complexity of the used system is quite low. The level of participation was moderate in the conception, low in the design, and moderate in the implementation phase. The perceived performance is poor in a considerable part of the company. Although, people show a quite high degree of acceptance together with a moderate level of usage and a quite high level of satisfaction. The users reported a quite high level of perceived control, also a quite high level of PU and PEU, and a high level of involvement.

Company 4 produces consumer packaged goods in two stages: in the first stage, the product is made from its raw material, and in the second stage, the product is packed. An APS had been implemented for the first production stage, which is characterized by a batch process flow with physically linked production equipment.

The level of participation during the conception phase was low, during the design and implementation phase the planners got involved. During the involvement of the planners, comments were made by them on the model – questioning design decisions on linking the various parts of the production process. However, their suggestions for improvement were initially not considered. After the system went live, the planners tried to work with the system for two months, after which the system was shut off again. A redesign project started to change the system according to the planners' insights on how the process should be modelled. It is interesting to note that the complexity of the model was not changed as a result, but the planners understanding of the model increased. The changes concerned decoupling parts of the production chain in the model. After a second go-live, the perceived usefulness of the system and the actual usage is at a quite high level.

5.2. Provisional results

The experiences reported lead to the following (provisional) conclusions that mark the starting point for further investigations:

Perceived usefulness and perceived ease of use appear to be correlated to usage. The feeling of control appears to be related to satisfaction and may influence the behavioural intention and therefore usage. The propositions made be the TAM are valid also in the cases presented above.

Participation in a later stage may influence system usage. A lack of participation in an early stage may not necessarily have a negative effect as long as it's compensated in later stages. Previous experiences may drive behavioural intentions which may be hard to change.

A more complex model needs some more involvement; a less complex model leads to less involvement and less usage. High involvement and a high level of perceived control may lead to satisfaction. High involvement and a high level of perceived control may be correlated with perceived usefulness.

Different levels of participation may lead to different levels of complexity. The complexity may also be dependent on the participation level in different stages. The feeling / perception of low complexity may lead to low perceived system performance (by users). However, a higher complexity does not automatically lead to a higher perceived system performance: only when the complexity is understood by the planners it is productive. Planners will understand the model complexity when they themselves have assisted in developing it. This leads to the following provisional conclusion: complex models are often better used because they have been developed using the knowledge of planners – in most implementations there is no other way. Only in cases where the complexity was modelled without their input, such as in case study 4, the usage of the system dropped. The level of perceived control may be influenced by involvement in the development and implementation process.

6. Conclusions and outlook

There is a lot of theoretical work available to better understand the topic in general and the particular relations. Due to the model complexity it seems to be impossible to prove the model by statistical data gained through a survey. By the cases analyzed so far there are some indications that support the proposed model. But there are also some indications that some relations proposed in the model have to be reconsidered, e.g. the role of the kind of decision, of former experience, etc. For future work some theoretical support for the assumptions has to be found. Generally speaking there's a need to collect more data and to observe more companies/ cases especially the whole process of design, implementation and adjustment.

As mentioned before, the study serves for the enhancement of several theories linked by the developed research model. The dynamics in modelling dependent on user participation hasn't been recognised so far, although it is an important topic for software companies as well as for enterprises introducing the DSS because user satisfaction and project costs are largely dependent on how good the initial adjustments are made and to what extend the changes are necessary. Due to the results gained so far and due to the importance of the topic it seems to be worth to continue with this research approach. In the long run a better understanding of the dynamics of modelling processes will lead to more efficient design and implementation processes, to better systems, to a better performance, and to more satisfied users.

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