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EXAMINING NON-REPRESENTATION IN ENGINEERING NOTATIONS

EMPIRICAL EVIDENCE FOR THE ONTOLOGICAL INCOMPLETENESS OF THE FUNCTIONALLY-RATIONAL MODELLING PARADIGM

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Abstract: The assumption that functionally rational notations can represent organisational spaces is central to engineering diagrammatical approaches in the delivery of advanced technology. This is reflected in a approach to notations which assumes objective, rationalistic ontologies. This form of rationalism in the modelling approach undermines notions of social context and social impact but, as such, has received little attention in the engineering literature to date. This paper opens the debate on research into notations and their relationship to sound method, suggesting that researchers need to rethink the ways in which the world is represented in engineering documentation, especially Requirements Engineering and Business Process Re-Engineering (BPRE). Empirical data from 9 companies and 48 people involved in manufacturing systems projects is presented which provides evidence for this position. *Copyright © 2002 IFAC*

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1. INTRODUCTION

Ontology is a term used in philosophy to deal with 'what exists' and is used here to deal with representation of what exists (Blackburn (1994)). Numerous notations are in use within the engineering community which attempt to represent what exists, for example, engineering drawings, organisational models and so on. However, to date very little work has appeared in the engineering literature that examines the ontological appropriateness of these representational approaches. The success of engineering approaches to the modelling and representation of purely mechanical artefacts cannot be denied. However, there are serious questions about whether such approaches can, ontologically, be easily transferred into social spaces. Increasingly, various branches of engineering have attempted to develop methods for representing social realities in diagrammatic form. However, these approaches remain firmly focussed upon a functional rationalism which believes that social space can be reduced to formally logical models (for example see domain analysis approaches published by

Goguen & Linde (1993), or object-oriented approaches to BPRE developed during the 1990's by, for example, Premerlani (1993) and Graham (1993)). Social systems and social impact modelling are particularly important for modelling notations in areas like Automation, Requirements Engineering, BPRE and Knowledge Management.

Functional Rationalism is a term coined in the literature to describe positivist influences in much information systems engineering theory and practise (Bickerton & Siddiqi (1993)). Most systems methodologies are based upon functionally rationalist premises. These premises have dominated research and practise, a fact which is well documented elsewhere (Klein & Hirschheim (1991), Galliers (1992), Myers (1995)).

Many papers have expounded models and notations based upon this assumption, without questioning whether the assumption itself is valid. Approaches that utilise functionally rationalistic assumptions include BPRE and Software Engineering Methodologies, in particular so-called 'structured' methodologies and object-oriented techniques. Engineering models associated with the deployment of automata are also, in general, dominated by a mechanistic view of organisational behaviour. It is apparent from techniques utilised throughout the requirements engineering literature that functional rationalism is the base rationalism in most techniques and approaches (Grenham (1997), Stapleton (1999)). This has lead to problems in engineering research and practice, most notably in Requirements Engineering (Bickerton & Siddiqi (1993)), and resulted in new departures during the 1990's in modelling domains and other social dimensions of advanced technology development (for example Goguen (1993), Goguen & Linde (1993)).

2. AMBIGUITY IN SOCIAL SPACES

It is well documented in the organisational literature that the inhabitants of social spaces do not act in logically rational ways, and serious ambiguities and complexities exist there which will frustrate attempts by engineers to represent, in formally logical terms, those spaces (Stapleton (2001)).

Participants and groups in organisations attempt to act rationally by determining the expected consequences of a set of possible actions. They often supplement this with (or subordinate it to) lessons learned from their experiences of the complex ecology of organisational life (March (1987)). Consequently, unambiguously 'clever' behaviours may not develop over time. Requirements and information models that represent information usage in organisations cannot be derived according to a standard view of unambiguous rationality. The derivation of such models during systems development assumes that people can make objective sense of organisational activity. According to organisational decision making theory, these assumptions are dangerous (Weick (1995), March (1999)).

Technical systems design often is part of a larger organisational systems design process (Mumford (1983)). Any attempt to engage in complex systems development must comprehend the rationalities behind organisational activity. Issues that will influence the process and outcome of a systems development activity are social constructions defined by the collective (Hilgarten & Bosk (1988)). However, organisational realities are not set in stone in some objective sense. Rather they are created dynamically through the complex micro-processes that constitute workaday life. Social reality is discovered in the act of creating it (Garud, Karnoe & Garcia (1998)). This discovery process exists in the interactions between people in the organisation.

It is therefore inappropriate to assume a rationalised reality which exists outside and independent of the subjective world of those who create this reality. In practise, advanced automation technology development and deployment projects (including BPRE, Enterprise Resource Planning systems, and other engineering solutions) attempt to understand social reality i.e. systems of information use in a social group. Furthermore, systems development is a social process (Stapleton (2001)). However, most approaches ignore this fundamental aspect of social rationality by overly focussing on a form of functional rationality. Social reality is constructed and reconstructed through social interaction, it does not exist outside of these processes.

In order to understand social action and the rationality which underlies it, we must understand the concerns to which social actions are tied. Events, concerns, developments and trends that organisational members collectively recognise as having some consequence and which, therefore, stimulate action must be addressed in any complex automation systems development process (Dutton & Dukerich (1991)).

Given these issues it is suggested here that modelling notations that adhere to a functional rationality are unlikely to be appropriate, nor indeed adequate, for systems development activities where social impact is a key issue. The inadequacies will be associated with the complexity and ambiguity of the social space concerned. Summarising, the research question addressed in this paper is: can issues associated with social impact of technology, such as change, complexity, uncertainty be sufficiently addressed by logical models?

3. RESEARCH APPROACH

An empirical study was conducted across nine manufacturing firms utilising a field research approach. The researcher interviewed forty-eight people who were actively involved in the advanced systems development project in their firm. In eight of the nine firms Enterprise Resource Planning (ERP) systems development was investigated. In one case the introduction of an EDI

system as part of a Manufacturing Quality strategic initiative was studied. Data gathering and analysis utilised a combination of quantitative and qualitative research methodologies.

Whilst an extensive range of non-parametric statistical analysis were available this paper presents simple descriptive statistics as per other similar studies (e.g. Murphy (1990), Grenham (1997), Stapleton (2001)). The utilisation of descriptive statistics (such as mean, standard deviation and median) is generally recommended for clarity and, in particular, where the statistical analysis provides a springboard into the richer, qualitative data. Is as often the case, the simple mean values, as a measure of central tendency, provides an excellent starting point from which to understand the data. This is in keeping with standard research practise where a technique comprising qualitative and quantitative devices is employed (Howell (1997).

4. FINDINGS

The researcher examined respondents' perceptions of the logical modelling paradigm. Interviewees were presented with a simple logical diagram which was then discussed at length with them in the context of activities within their own organisation. During the discussion they were asked the extent to which they felt that these models adequately represented information use in their firm. The results are summarised in table 1.

It is apparent from the table that no company returned mean values that indicated that they found the logical modelling approach satisfactory. Interestingly, there was not a significant difference between the perceptions of technical and non-technical staff perceptions. Whilst technical staff found it easier to understand the logical models presented to them than did the non-technical staff, they also identified serious problems with the modelling paradigm.

What is striking from the results is that 'change' was not the key problem, as expected from a review of the organisational literature. Rather, the issue of complexity was the most serious problem that interviewees faced when using these representation techniques. The models they had encountered in their project work, all of which were based upon a functionally rationalistic paradigm, simplified away key issues in the project, and created blind-spots for project teams members. Indeed, a common comment was that, once developed, logical models of the organisational information processing activities were rarely alluded to and 'simply gathered dust on the top of a wardrobe'. When the interviewer requested document samples project team members generally had difficulties locating the modelling documents they themselves had created.

Interviewees were also asked to add any other issues they felt contributed to difficulties with these models, but no issues were identified that did not relate to either complexity of, or change in, the world under scrutiny.

In order to understand the problems people had with the functionally rationalistic approach, which assumes that the world can be reduced to relatively simple set of diagrams and symbols, the researcher included a qualitative study into people's perceptions of the information technology deployment process. The key concerns of participants were explored in the study.

Table 1 Interview Results: Mean Values of Responses by Company

COMPANY:	A	B	C	D	E	F	G	H
Can logical models adequately describe information use?	**2.6**	**2.8**	**2.0**	**2.5**	**2.0**	**3.2**	**2.2**	**2.3**
- Would a logical model be too complex to understand?	**3.9**	**3.4**	**4.3**	**2.0**	**3.2**	**4.2**	**3.8**	**4.0**
- Would a logical model change too often?	**3.1**	**2.8**	**3.5**	**2.0**	**2.4**	**2.8**	**1.8**	**4.3**
Were Project Documents Helpful?	**2.4**	**3.1**	**3.0**	**3.3**	**2.2**	**2.0**	**1.5**	**3.7**

Key: Likert values range on an ordinal scale from one to 5.
1 = not at all, 3 = somewhat, 5 = very much

Technology deployment concerns related to various aspects of 'knowledge' and emerged as the project progressed, reaching a crescendo in the immediately weeks prior to, and in the months subsequent to, implementation of the new system. These concerns especially arose in the following contexts:

1. Key Phenomena are *too complex* to be known
2. We cannot know the *social impact* of the developments
3. We cannot not know what will be the *impact upon business operations*
4. *Clarifying Issues* in general

Each of these will now be expounded in turn.

4.1 Key Phenomena Are Too Complex To Be Known

The projects in which interviewees were engaged were enormously complex. A common example of where this emerged was in the context of a common view ('Global' or 'Core' model) of manufacturing operations. When analysing organisational activities early in the project the issues that arose seemed to be fathomable and were often depicted on diagrams or textual narrative and reified into the new Enterprise Resource Planning (ERP) system

during system construction and parameterisation. However, when participants began to test the system it emerged that the local site *modus operandi* significantly differed from the global view of the firm as embodied in the new system. The local detail of organisational operation at a day to day level was frighteningly complex whilst the system had been derived from an organisational view which did not, and could not, account for these complexities.

4.2. Social Impact

The respondents had significant misunderstandings as to what the project meant for them and/or the organisation at large. An example of this is manifest in discussions of *expectations*. Many respondents described how consultants had set very high expectations at corporate level. The system was supposed to seamlessly integrate the global enterprise according to a single core model of the business. However, when participants began to work with the test system they found gaping holes in the functionality. Respondents often felt that they stumbled upon these functional breaches by chance. As a result the interviewee became extremely uneasy as to what else might be missing.

A story that exemplifies this was the 'Dual Sourcing' issue in Company B. This firm relied upon a flexible production subcontracting environment in which the site positions subcontracted firms to perform certain production operations where increased capacity was required. The project studied in company B was one which introduced a large ERP system upgrade to the firm in order to satisfy Year 2000 compliance objectives. It was understood that dual-sourcing was a key strategy and enabled the manufacturing plant to respond in a very flexible manner to uneven demand. The following extract reveals the essence of the story…

> 'I learned that the systems are shipped out with very little testing. The problem is that when the initial guy came in from the consultants he promised the earth, moon & stars. But when it came to implementing the system we were told that the system couldn't deal with dual-sourcing. Assistance for identifying workarounds was given but this should have been addressed earlier… The system is not able to handle a flexible subcontracting environment and there wasn't much choice [of solution], the solutions we were coming up with were restricted by the system… our hands were tied by the inflexibility of the system. These issues are still being resolved'
>
> Project Team Member

This scenario indicates the tension between management concepts at an abstract level and the operationalisation of these concepts in everyday organisational reality. There were very many neat models created during these projects. These models created a global, integrated picture of the business, and therefore were used to specify system functionality across many different organisations within each firm studied. Different manufacturing sites were to operate according to a single, global, corporate model which defined best practise for the business sector inhabited by that corporation. These best practises were associated with industrial engineering (e.g., World Class Manufacturing Goals) as well as finance, purchasing and all other primary business and engineering operations. The systems were built according to the 'best practises' as defined in, and embodied by, the systems development models.

However, respondents told how their organisations were not homogenous. Many felt that it is this lack of homogeneity that gives the individual sites a competitive edge. The result of this anomaly as described by respondents was a discontinuity between the management concepts embodied in the system and the information made available to organisations as they came to grips with the new environments. Simple abstractions did not sit easily in complex realities, as is evident in the following story…

> 'The devil is in the detail. Reports didn't reflect the complexity of what we wanted… the consultants were like the one-eyed man in the kingdom of the blind. The draft reports took four weeks to get back. We knew we wanted different real-time reporting and there was critical information we needed from day-to-day… there was no confidence in the accuracy of the data'
>
> Managing Director.

4.3 Business Process Impact

Respondents in all firms described concerns about the impact of new business processes upon the organisation and a deficit in knowledge of these issues. There was a general feeling that people did not appreciate the complexity and enormity of what was being asked by the project of the organisation at large. This was often described as a step into the unknown. This complexity could not be adequately catered for by the modelling and documentation paradigms which underpinned the systems development approaches adopted in the projects. Some respondents felt that the project consultants had an enormous lack of knowledge. The *knowledge deficit* was so marked that in some cases the interviewees described how it was impossible to have meaningful discussions with the consultant. These problems typically surfaced in the nitty-gritty of sensemaking close to cut-over to the new system. This perception often lead to fears about what a massive, complex system would do to the organisation when it went live with all its attendant new organisational processes which respondents had not fully comprehended.

4.4 Clarifying Issues

In many cases project consultants played a key role in helping people clarify issues. This was perceived as a key role of consultants. Some respondents explained how consultants were a great help to them in this process. In this context the creation of logical models helped to clarify some key issues. However, the evidence suggested that it was the *process* of creating the models, rather than the models themselves, which was helpful. Effective consultant support enabled respondents to understand how the new system functioned and what this new functioning would mean for the organisational sub-groups involved. The key element of this process was very much an iterative dialogue. Meaning was constructed as the consultant and interviewee engaged in active sensemaking (as per Weick (1995)). This typically involved engaging with the new system, particularly during testing and implementation, and having lengthy discussions as to how the system operated. However, there was evidence to suggest that there are two stages to this process of learning. One is the '***educational' stage*** prior to going-live where people become familiar with the business concepts. The second stage makes ***practical sense of the new system*** after the project has gone live. There is also evidence to suggest that traditional (i.e. formally rational) approaches to projects encountered many problems because of a lack of emphasis upon these sensemaking processes, particularly when capturing requirements and modelling the new systems and their concomitant organisational settings. Consequently, there were major gaps in the diffusion of new concepts embodied in the new technology. As a result respondents in company G experienced major trauma because the system simply didn't make sense to the organisation after it went live. Similar situations were also described in Companies A and B.

In order for the consultants and other team members to be effective they required excellent interpersonal skills and a high level of business knowledge. The models simply could not compensate where team members did not possess these skills. Many of the key issues associated with the social impact of new technology required a highly intuitive and sensitive approach because of the complex nature of these issues. When introducing the new technologies the sheer complexity of the organisational field required that project team members had extensive knowledge of organisational activity. In no case was project members' grasp of modelling techniques cited as a useful skill. The following short collage of quotes from across the firms illustrate these factors:

'One consultant had a good materials background and was excellent'- Project Team Member

'The consultant knew the business. He was very good, a genuine guy. The system worked because of him, he was a key success factor. He would muck in at my level and present me with the options'- Project Team Member

'Consultants are module specific. They don't know the impact across modules. The business knowledge isn't there, only SAP knowledge'- Senior Manager

'The consultant had poor interpersonal skills. He would wind people up intentionally to try to break people out of the beaten track. This was a poor approach. People don't react well to that. The intervention was too abrasive. He should have engaged people in debate.'- Senior Manager

It is evident from the above brief selection of quotes that a number of respondents felt that the consultants did not adequately fulfil the sensemaking support role required. Certainly, there was no evidence to suggest that formally logical depictions of the organisational were referred to when assessing the potential social impact of the new technologies. This was typically because consultants had inadequate knowledge of the business area, poor interpersonal skills or both. As a result many respondents described themselves as 'having to find their own way'. This metaphor of a journey through hazardous terrain was common. It is important to note that the journey was rarely linear i.e. people returned again and again to the same issues in order to make sense of them. This was accompanied by a sense that, because the consultants did not understand the interviewee, that the consultants were unable to adequately respond to pressing needs. This was in spite of extensive scenario modelling and functional design modelling. Ambiguity in the organisational space was simply out of the scope of both the models and the project consultant who was drafted in to help create them. The following final excerpt illustrates this

'My consultant wasn't much help. I felt like I was speaking to a child. Things were very ambiguous. For example, he would set up the system to get it changed and after fifteen minutes nothing happened – you just sat there. During training sessions the system wasn't set up correctly. He didn't understand the business.'

Project Team Member

5. CONCLUSIONS

The results indicate that there are fundamental problems associated with the functionally logical modelling paradigm, especially when applied to social spaces. This was predicted by the review of the literature set out in the opening sections of this paper. However, there was not conclusive evidence to suggest that that the modelling process is to be avoided. Findings showed how the inter-subjective dialogue created by, and organised around, systems models was useful in the sensemaking processes central to organisational learning amongst project team members. The learning processes were the key, rather than the models themselves. In summary, the evidence suggested that

1. The logical modelling paradigms need to be revisited, particularly in the area of social impact of technology
2. Organisational learning processes cannot be adequately compensated for by any logical modelling process: learning processes, not modelling processes, are the key.

Engineers need to join with their counterparts in organisational studies and communications studies in order to develop methodological paradigms which will deliver effective processes, rather than highly formalised notations, by which social impact can be successfully captured, addressed and managed.

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Appendix 1.
Firms That Participated in the Research Study:

- ABB Transformers: Electrical Engineering
- ABS Pumps: Mechanical Engineering Products
- Allied Signals Ireland: Electrical Engineering
- Allsop Europe: Consumer Electronics
- American Can Company: Metal Packaging
- Louisiana Pacific Europe: Building Products
- Norton Pharmaceuticals: Healthcare
- Honeywell-Measurex: Electrical Engineering
- Waterford Crystal: Glassware