Knowledge in Planning Scheduling and Control.

Track: Operations Planning, Scheduling and Control.

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Abstract

To provide responsive order fulfilment within manufacturing organisations, planning, scheduling and control (PSC) processes are often human intensive. It is important in these scenarios to understand the encapsulation and application of knowledge that supports associated individual ,team and networking activities. Research is being undertaken by the University of Nottingham in collaboration with a consortium of large manufacturing businesses across a number of sectors to develop an understanding of established and evolving PSC processes. The application of knowledge is one aspect of this research. Here we identify key issues in understanding the role of knowledge within a responsive PSC process.

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Introduction

PROCHART is an EPSRC IMI funded project[1] established to develop an improved understanding of the planning, scheduling and control (PSC) process and its contribution to responsive order fulfilment, leading to the development of a methodology for the re-design of PSC processes across a range of business sectors. The project leads on from research already conducted on responsiveness (Kritchanchai and MacCarthy 1999) and human scheduling (Crawford and MacCarthy 2000) at the University of Nottingham and complementary work on responsiveness (Matson and McFarlane 1999) at the University of Cambridge.

It utilises a consortium of members including four established large manufacturing companies, two academic partners (University of Nottingham and University of Cambridge) and a software development company specialising in process modelling. The research is based on field study and will be completed over a three year period. At this stage familiarisation visits have been conducted and a workshop has been held prior to more in depth field work.

The project recognises the holistic nature of the PSC process and intends to extend the understanding of the interplay between components of the process (people, support systems and activities). The central role of people in these processes is emphasised. One of the overall objectives of the project is to extend the understanding of the characteristics and interaction of the human element, within the development of a holistic perspective, identifying roles, interactions, group and team structures, knowledge and support requirements, that enable responsiveness.

This paper considers one aspect of the project, the nature and significance of knowledge utilised within an effective PSC process. By reviewing related work on responsiveness and human factors, and evaluating the findings of the consortium workshop, it sets out to establish relationships between aspects of knowledge and its management and activities within PSC processes that support responsiveness. These findings will then provide a focus for the field study research.

Research Approach

Research has been conducted so far through literature review, consortium member familiarisation visits and a workshop. The research intent is to establish the role of knowledge in supporting effective decision making, communication and management of the process and its impact in relation to enabling responsive order fulfilment. To understand the human elements of the 'As is' PSC process in relation to responsiveness the following aspects were investigated through a literature review: responsiveness, people and teams, and knowledge management.

Additionally the consortium workshop activities were utilised to establish the perceptions of the industrial consortium members in relation to two key areas; whilst one breakout group in a workshop session was involved in defining responsiveness and its context, the other provided views on, and a model of, people and process management in the PSC process.

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[11] Engineering and Physical Sciences Research Council (EPSRC Grant GR/N34284/01): Towards World Class Performance In Planning, Scheduling And Control: From Progress Chasers To Responsive Teams

The workshop was also valuable in establishing issues of direct relevance to each business within the consortium through which common themes were identified. The majority are currently undergoing significant organisational and/or systems change. All highlighted the importance of identifying and managing knowledge effectively. This will involve recognising the critical areas in which human intervention impacts significantly on responsiveness and therefore application of best practice, including knowledge management, is essential. By recognising these areas the business process and organisational changes can be designed and implemented to support responsiveness more effectively.

These two lines of research are drawn together to establish the types of knowledge that need to be understood and focused on in the ensuing field study research.

Literature review and workshop outcomes

Responsiveness

The definition of responsiveness within a business process context needed to be established through literature review and workshop feedback. A multitude of definitions have been generated in the literature and tend to be dependent on the researcher's perspective whether in relation to business process reengineering, flexible manufacturing, time-based compression or agile manufacturing.

A working definition of responsiveness was developed by industrial participants at the workshop. Responsiveness is "*the ability to identify, assess and react to stimuli in a proactive and appropriate way, which is time-based and aligned to the business objectives*" Within the definition the expression 'appropriate way' needs to be clarified. It includes within it the need to align responses to business objectives considering trade-offs such as cost vs. benefits, and the appropriateness of the time frame to the response made.
The definition needs further development as the ability to respond to unforeseen occurrences needs to be built into a responsive business. In this case the response may be reactive rather than proactive; the other conditions should still apply.

The workshop group considered responsiveness further and identified some common concerns in relation to:

- The cost of responsiveness; how it can be ascertained and recognised in decision making;
- The significant contribution of the knowledge of people to responsiveness e.g. the individual's knowledge of an appropriate response, or of the unusual nature of the stimulus and the need to refer the situation to others;
- The lack of established/recognised processes through which decisions are made which may include the need for a 'database' to provide knowledge on previous responses ensuring 'best known practice' and consistency, and a procedure for handling both common, rare or unfamiliar stimuli.

All had a concern in relation to their dependency on key knowledgeable personnel and in relation to where knowledge is located or held within a complex system.

The definition generated by the workshop bears some similarity to the definition provided by Matson and McFarlane (1999) in work undertaken to develop a production responsiveness audit. Here responsiveness is defined as "*the ability of a production system to achieve its*

goals in the presence of disturbances" where disturbances can be positive or negative in effect. Within this definition it is stated that "*Responses must respect multiple goals: where more than one goal for the system has been adopted (e.g. cost per unit and delivery), both goals must be simultaneously taken into account*".
The research presented in their paper also identifies factors influencing responsiveness under three categories; *recognition capability*, *plant capabilities* and *decision making capability.* Reviewing these factors in more detail provides an insight into knowledge requirements.

In relation to the human contribution to responsiveness the factors most influenced by human intervention, and therefore in which knowledge is key are those classified by Matson and McFarlane (1999) as *recognition capability* and *decision making capability*. *Recognition capability* is 'information gathering and interpretation regarding system variables (e.g. stock levels, resource availability); disturbances (e.g. sales, forecasting, breakdowns, supplies)'. *Decision making capability* is the 'ability to make plant capability deployment decisions, which take account of: disturbances and system variable/states; cost benefit considerations; knock on effects etc…'

Kritchanchai and MacCarthy (1999) in field studies of eight Thai and six UK companies conducted a thorough literature review in relation to responsiveness and through this and field study results identified four components of responsiveness:

- ***stimuli*** - the responsiveness drivers
- ***awareness*** – to be aware of the drivers and what is needed to respond
- ***capabilities*** – the ability to respond to different drivers
- ***goals*** – the targets or objectives of each company in its environment

From this work Kritchanchai (2000) developed the following definition of responsiveness: *Responsiveness is the ability of a system to identify significant stimuli, to be aware of their impact and the need to provide appropriate capabilities to respond, and to deploy those capabilities effectively whilst achieving set business goals.*

The four components of responsiveness identified by Kritchanchai and MacCarthy can also be considered in relation to knowledge requirements. In relation to the human contribution to responsiveness it is hypothesised by the authors that the component most influenced by human intervention, and therefore in which knowledge is key is, ***Awareness***. As an illustration , the experienced planner/scheduler in anticipation of future requirements may hold extra stock or capacity, or establish closer relationships and forewarn suppliers, or have already identified lower priority work that can be re-scheduled to a later date, or work that can be re-routed to make space. To make effective decisions on the stimulus and be pro-active (s)he is aware not only of the capabilities of the system, but also of potential stimuli (so that the response may be proactive) and the business context of decisions made in relation to business goals, which may present themselves as priorities and constraints.

Further to this, the authors conjecture that the planner/scheduler also applies knowledge of the business process, and of relevant individual contacts and networks, in order to decide on a response and action it via effective communication and influence. Given this, a key research question is raised with regard to the human *awareness* contribution, which is how organisational goals are transmitted across an enterprise.

This view is supported by work undertaken by Crawford and MacCarthy (2000). The research analysed schedulers 'actual' activities through observation in the field and identified three categories of task and three categories of role behaviour. The three task behaviours are *formal task behaviour* in which tasks that the business formally recognise as scheduler tasks are carried out; *house-keeping task behaviour* in which the scheduler organises data according to the way (s)he carries out work, and *compensation task behaviour* in which (s)he compensates for some level of problem or failure in the overall system. The findings are that in real world situations schedulers engage in tasks that may not be formally recognised but are often essential and in themselves require knowledge.
The three role behaviours consist of the:

- *Link and net role* which includes the development of interpersonal networks, informal bargaining, friendship and favour networks and mediating and may be considered as the *interpersonal role behaviour*
- *Hub and filter role* which is an *informational role* in which (s)he acts as an implicit and explicit information hub ensuring that information is accessible and visible. This includes identifying the relevance of information and filtering it.
- *Balance and valve role* which captures the *decisional role* behaviours of problem predicting and problem solving, changing plans and instructions, and allocating resources.

The three role behaviours described provide further insight on the knowledge requirements of 'real world' schedulers, and by extrapolation planners.

Implicit in the results is that in these dynamic processes and environments, peoples' input is significant and is very much based on their perceptions of the situations and their own objectives and roles and will be based on complex knowledge and judgement of their situation.

Further to this Crawford *et al*. (2000) raises the proposition that '*a paradigm shift has to be made to consider human scheduling practice primarily as a social and organisational function, with the cognitive functions incorporated within, rather than defining, this wider structure*'. In relation to organisational structure, planning and scheduling software, people and manufacturing processes Crawford *et al*. state that '*the interdependency of these factors within a business generates contextual expectations that influence scheduler behaviour and performance*'. This view of decision making within the scheduling arena is further supported by the findings of McKay et al., (1995) who identified that schedulers will often have a number of different schedules, the political schedule, the schedule that he believes in and the 'optimistic' schedule he pushes the line to achieve. He also has 'His private or inevitable view of what was going to happen despite what he or others did'.

A comparison can be drawn between these findings and the perception of industrialists present at the consortium workshop, in which a group was tasked to consider the human and managerial aspects of the PSC process and how it might be modelled. This group developed a generic model of the planning and execution cycle that clearly identified human intensive processes within the cycle. This included processes of 'simulation' and 'negotiation' as essential human intensive tasks. The significance, complexity and degree of formality of these processes at different stages of the cycle varied for each business, although they did exist in each. In this model, simulation represents the activity of assessing the impact of a decision in relation to its effective achievement and normally includes recognition of the

perspective of individuals through which negotiation will take place. In some cases this process may be incorporated into a formal system. Negotiation and communication were identified as important processes, between planners and schedulers, and schedulers and shop floor personnel. For effective negotiation each party should have appreciation of the 'actuality' of the other's situation so recognising how plans, schedules or instructions may be 'interpreted' and therefore actioned.

The above findings indicate that it is experience (and knowledge) that enables planners and schedulers to respond appropriately within a context that is both cognitive and social, formal and informal.

Knowledge and it's Management

Extensive research has been conducted in relation to knowledge and its management in relation to consultancy, healthcare, financial and engineering organisations. In engineering the focus has been on product design and development activities whilst research on its application at the operational level is limited; this is reflected in the level of software development in different areas.

Hansen *et al*. (1999) identify two alternative approaches to knowledge management through their study of consultancy and engineering companies; these are of *codification* or *personalisation*. They also postulate that effective firms focus on one of the two approaches. *Codification* relies on an ability to capture, store, codify and retrieve knowledge. By contrast *personalisation* relies on establishing effective communication between 'experts' who are the knowledge repositories. The latter is employed where tacit knowledge is rich as the process of sharing deep knowledge becomes too time consuming, expensive and slow. According to Hansen *et al*. (1999) when deciding on the best approach the business must ask '"do your people rely on explicit or tacit knowledge to solve problems?" … When people use tacit knowledge most often to solve problems, the person to person approach works best.' Their findings raise key questions in relation to knowledge management within an operational process such as PSC.

Knowledge for Responsiveness in PSC

The above findings serve to demonstrate the complex nature of human intensive PSC processes and specifically those aspects that enable responsive order fulfilment.

Some of the more complex activities that require expertise and associated knowledge have been identified through the literature review and workshop feedback. The roles and application of knowledge have been classified to support a process for identifying knowledge requirements; this information is presented in Figure 1 and 2.

See Figure 1

Figure 1 identifies the relationship between activities undertaken by planners and schedulers, identified through the planning and execution cycle developed at the workshop, and the role of knowledge required to support these activities, as identified through the responsiveness literature. The information presented draws particularly on the work of Kritchanchai and MacCarthy (1999) that identifies awareness as a key component of responsiveness and identifies the other components as stimuli, capabilities and goals. In order to be effective, awareness of, and therefore knowledge of, stimuli, capabilities and goals is required. The research conducted by Matson and McFarlane (1999) does not contradict these findings but

examines responsiveness in relation to capabilities. Within the *decision making capability* is a recognition that not only are decisions based on an awareness of stimuli, plant capability and goals, but also that decisions need to be informed through an understanding of their 'knock on effects'. The recognition and simulation of these situations and alternatives is by no means straight forward. The knowledge required to simulate these situations has been added to the final column in figure 1. as the knowledge required may differ from that associated with recognising and understanding capabilities. The knowledge required is temporal in nature, but more importantly, may consist of tacit knowledge gained from experience of 'knock on effects' in previous real world scenarios.

See Figure 2

Figure 2 draws on the work conducted by Crawford *et al*. (2000), as well as the literature on responsiveness, to identify the role of knowledge in supporting the scheduler's role behaviours. Here the role of knowledge is specified in relation to *inter-personal*, *informational* and *decisional* role behaviours. It should be observed that the decisional role may be considered to consist of the simulation and negotiation activities already described in relation to knowledge requirements in figure 1. The role of knowledge within the two other role behaviours (and shaded in figure 2) has a different focus and will need to be more fully evaluated within the field study.

Conclusion

A rich picture has been developed through a literature review and the findings of a consortium workshop that identifies the significant roles that knowledge must play in the PSC process to support responsiveness. This has highlighted the role of knowledge in the context of planners' and schedulers' activities and roles. This analysis will be used to focus efforts in the field study into appropriate areas of research providing a basis from which to identify the data that needs to be collected in relation to the most relevant aspects of knowledge and its management in the context of the roles it needs to perform. This should ensure that the research identifies the knowledge requirements that support the human intensive activities that are key to achievement of responsive order fulfilment.

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Figure 1 Relationship between PSC activity and role of knowledge required

Activity	Knowledge Required To:			
Simulate to make decision(s)	Recognise **goals** and trade offs between them	Recognise **capabilities** of process and manufacturing	Anticipate and interpret **stimuli**	Recognise the impact of decisions on the operation - **knock on effect**
Negotiate plan, schedule to facilitate its implementation	Recognise others' **goals** and perspectives	Recognise **capabilities** of process and manufacturing	Anticipate and interpret responses to plan	Recognise the impact of decisions on the operation - **knock on effect**

Figure 2: Relationship between planner/scheduler role behaviours* and role of knowledge required
*Role behaviours as defined by Crawford *et al.* (2000)

Role Behaviour	Knowledge Required To:			
'Link and Net' ***(inter-personal role)***	Recognise others' **goals** and perspectives	Recognise **where knowledge resides** and value own knowledge	Understand **network processes** and norms	Understand a person within a **social context**
'Hub and Filter' ***(informing role)***	Recognise others' **goals** and perspectives	Recognise and **understand the process**, who to inform and their information requirement	Interpret the **stimuli** in relation to the informing response requirement	Recognise the impact of decisions on the operation - **knock on effect**
'Balance and Valve' ***(decisional role)***	Recognise **goals** and trade offs between them	Recognise **capabilities** of process and manufacturing	Anticipate and interpret **stimuli**	Recognise the impact of decisions on the operation - **knock on effect**