

PROCHART TOOLKIT TO RE-DESIGN PRODUCTION PLANNING, SCHEDULING AND CONTROL PROCESSES

J.E. Guinery, B.L. MacCarthy

Operations Division, Nottingham University Business School, Wollaton Road, Nottingham, Nottinghamshire, U.K.

Abstract

Production planning, scheduling and control (PSC) activities are critical to manufacturing businesses competing through responsive order fulfilment. With the current drive for businesses and supply chains to be responsive, a large scale three year empirical study was conducted with five cross-sectoral industrial partners to investigate the reality of PSC practice and to establish ways to improve it. From this in-depth analysis, PSC design rules have been established and used to develop a Toolkit to assist businesses in re-designing their PSC organisation and PSC processes.

This paper describes the research and Toolkit development stages and content. It also evaluates the Toolkit's performance in its first full application to a business. The Toolkit is extensive, it is therefore intended that the paper should describe its focus and provide an overview of its applicability and content.

Keywords:

Production planning, scheduling, organization design, business processes, decision making, knowledge

1 INTRODUCTION

There are many pressures on businesses to improve their responsiveness and order fulfilment performance in order to compete effectively in modern day challenging and dynamic markets. In view of this, five large and complex manufacturing businesses operating in the UK joined a research project run at Nottingham University to research 'best practice' in production planning, scheduling and control (PSC) looking towards improved responsiveness.

One outcome of the research is a PSC re-design Toolkit that has been developed to:

- support PSC process redesign, providing guidance on the organisational and operational options available to improve PSC performance.
- be utilised where there is a need to improve performance or re-design PSC to suit other initiatives. Such initiatives include the introduction of new information systems and /or other operational changes e.g. moving to Lean, focused manufacturing or to mass customise products etc...

The Toolkit takes a business through an analysis of its operation and PSC architecture and processes 'as -is' to first identify its PSC requirements and then provide recommendations that address a number of aspects of PSC.

The main aspects addressed are:

- **The PSC architecture:** essential PSC activities, their relationship to each other including significant planning levels and the form of interfaces between functions.
- **The preferred forms of PSC processes:** to support decision making (e.g. informal networks, formal meetings etc...), the extent of formalisation of processes and work environments to support elements of informal decision making.
- **Human and information system roles:** where expertise is required, its form and how decision making can best be supported by information systems.

Analysis and recommendations are made at different levels. For example, at the organisation level the analysis of interactions between functions in the business is undertaken through analysis of data on the number, form

and impact of the overall interactions, to examine which functions may need to be co-located. In a later section of the Toolkit some of the key decisions are analysed at a detailed level to establish the form of the decision inputs (knowledge type, content and source) and the implication this has on requirements placed on people and information systems and the roles they need to play.

2 RESEARCH APPROACH

The project, called PROCHART, set out to understand PSC and identify 'good practice' through the in-depth analysis of PSC practices in five cross sector businesses. The project differentiates itself from many other operations management research projects by taking an holistic perspective of PSC. It recognises the complexity inherent in many manufacturing organisations and looks at the key elements of PSC - process, people and information systems. It recognises not only the significance of the elements but also of the interactions between them. In particular the research views PSC as a decision making process and recognises the human element as being highly important in providing responsive performance. The analysis draws on multi-disciplinary research including that in decision making, operations management, knowledge management and organisation behaviour.

The research sets out to establish options that a business can implement to improve its PSC organisation and practice. The Toolkit, developed from the findings, shows options for businesses to pursue given their circumstances and environment. It is not prescriptive in nature, in fact far from it. Even if it were feasible to recommend standard 'good practice' it is not the intention of the re-design process to do so as it is often the unique way in which a business manages its own complexity that provides it with competitive advantage.

In the initial research it became apparent that the businesses studied utilised a broad range of approaches to the management of their PSC processes. In most cases these successfully supported specific responsiveness requirements in each business scenario. The factors affecting preferred forms were not necessarily sector or product specific but instead emanated from the situation in

which the PSC process resides, characterised by its own decision making environment.

As 'good practice' is highly dependent on the specific situation in which PSC resides, the identification of contingent factors on preferred practice has been pivotal to this research. The literature review that informs the research therefore delves into significant factors that influence decision making processes. Once these are identified it is a premise of the research that ways of modifying the PSC organisation can be established that will influence these factors and therefore support PSC decision making.

So the aim has been to identify contingent factors and establish their individual or combined impact. Then, having identified their implications, determine how PSC can be re-organised to simplify or more effectively manage complex decision making and thereby improve performance.

3 LITERATURE REVIEW

Taking the perspective of PSC as a decision making process it is important to examine previous research on:

- Organisational behaviour and design.
- Production management system (PMS) modelling and design.
- Decision making.
- Knowledge management, particularly in relation to managing non-explicit 'know how'.

The literature review focused initially on establishing definitions and terms, then on the factors that impact on decision making and the ways in which PSC can be re-designed to simplify and / or support complex decision making.

Research in organisational behaviour identifies the need to understand the factors on which preferred practices are contingent. The impact of levels of functional differentiation and integration [1], and their pros and cons for an organisation, clearly will impact on decision making and the processes that need to be supported. This aspect is also identified in knowledge management literature where the distribution of knowledge throughout an organisation is demonstrated to affect decision making processes [2].

Preferred structures for PSC need also to be considered with respect to the appropriateness of hierarchical production planning as apposed to decentralised planning [3], as well as the impact of de-coupling points (where buffer inventory is held within manufacturing) [4] and the interrelationships with respect to authority, task and roles [5].

The Knowledge Management literature has flagged the need to truly understand the nature of decision making. For instance, if knowledge is to be shared for decision making, is there also a need for knowledge transfer or the generation of new knowledge [6] and how can such processes be supported?

The issues of the impact of 'unsteady manufacturing' environments on the contingent aspects of preferred decision making processes were identified from a number of sources including the decision making literature [7]. In-depth empirical research into decision making in real world contexts indicated the relevance of the recognition primed decision making (RPD) model, which recognises that decisions are relatively ill-structured and decision makers work from experience of similar situations, to generate solutions and evaluate their suitability. Here situation awareness has been found to be critical. This has many implications in relation to the roles of humans, their requirements, the types of knowledge they need, the ways they need to interact with each other and their

environment, and appropriate ways in which information systems can support them.

With a view to re-designing PSC processes, approaches were drawn from a range of organisational design literature sources. These included the socio-technical systems approach [8], and an approach that recognises requirements from an information processing perspective [9].

Additionally, to support analysis different modelling tools have been investigated and selected and include two modelling techniques used in the GRAI (Graph with Results and Actions Interrelated) approach to production management system design, originally developed at the University of Bordeaux [10]. GRAI grids model decision making architecture in terms of decision centres and the relationships between them. GRAI nets model inputs to decisions. Both techniques have been modified to support data capture requirements specific to this research. The RPD model [7] of decision making as well as GRAI, have been used to support the visualisation of PSC organisation and decision making processes.

The issues drawn from the literature review have lead to the identification of two key aspects of the research:

1. The contingent nature of practice and the potential contingency factors that should be researched.
2. The significance of characteristics of the decision making environment.

The literature has also informed the selection and development of PSC process modelling tools.

4 METHODOLOGY

4.1 Approach and process

The project took a grounded approach to identify 'real world' practice and model processes (including decision making) to establish a rich picture and develop findings from observation.

To understand the relevant aspects of PSC (notably its elements and their interactions: people, process and information systems) there was a need to capture and analyse information not only on decision making architecture and PSC processes, but also to capture the characteristics of the decision making environment on which PSC practice may be contingent.

The stages of data capture and analysis are shown in Figure 1.

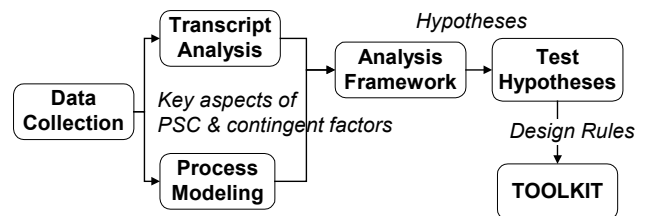


Figure 1: Stages of analysis.

The stages of analysis consisted of:

- Data collection from in-depth interviews conducted at five consortium businesses.
- Analysis of interview transcripts using NVivo software [11] to identify key issues and characteristics of PSC, the business and decision making environment.
- Modeling to visualise PSC organisation and processes – models were modified to also capture and analyse the relevant characteristics of the environment.

- Development of an analysis framework to analyse information from each business in order to identify the relevant aspects of PSC and explore the factors on which preferred practice is contingent. In each case, through this analysis, to generate hypotheses on 'good practice' and contingencies, which, once tested, may be applied as design rules within the Toolkit.
- Development and application of a PSC audit to further research key characteristics and PSC practice that are considered significant and to test hypotheses through the audit of 6 additional businesses.
- Establishing the design rules from the non-refuted hypotheses and developing the Toolkit as a vehicle for their application.

Data was validated at various stages of collection. In initial stages the models generated from interview data were presented to participants for validation, later reports on findings were presented to the company for discussion and provided as hard copy for validation. At all stages workshops were held and approaches and findings reviewed by participants.

The following stages are examined in more detail:

- The PSC analysis framework.
- Generation of hypotheses.
- The audit.

4.2 PSC Analysis Framework

Initially the research intention was to identify characteristics of a manufacturing business that would enable it to be categorised into an identifiable group of businesses with similar PSC requirements. However, the infeasibility of this approach became apparent as the analysis was undertaken. There were two main reasons for this. Firstly, the number of significant parameters seen to influence PSC practice was enormous. Secondly, a business may be very similar to others in most respects but differ in one that results in PSC 'good practice' observed in other businesses being completely impractical for that business. It became apparent that:

- The initial intention to classify businesses into types based on a specific range of parameters is not feasible.
- A three stage analysis framework was required to identify the characteristics and assess the impact of the PSC decision making environment.
- Any single business may have a number of different PSC environments each with its own and different PSC design requirements.
- Not all factors that affect PSC options can be included in the analysis; there are in fact many influencing factors, such as management style, organisation and / or supply chain (SC) position and size and geographic location, which impinge on PSC practice but cannot all be included.

Figure 2 shows the 3-stage framework developed to analyse each business. Key characteristics of the PSC environment in stage 2 include 'steadiness' of production, event timings and knowledge distribution. Key characteristics of the business include physical layout of resources, operations policies and product and process complexity.

4.3 Generate hypotheses

Information on each of the businesses was compared and contrasted and their practices looked into. Then, through a combination of comparison and literature review, hypotheses were developed and their validity explored in relation to each business studied. Their implications were

then identified in relation to PSC re-design and the non-refuted ones were translated into design rules for the Toolkit. Their validation is limited as the sample of businesses is small. Hypotheses that were not refuted by evidence are incorporated as design rules.

Noted below for illustration are three of twenty five hypotheses, translated into design rules:

1. Preferred decision making processes are dependent on knowledge distribution and decision timescales:
 - Distributed knowledge increases the need for mechanisms to be in place to support cross functional decision making.
 - Decision timescales impact on the extent to which formal approaches can be adopted and the ways in which decision makers may compromise decisions.
3. Decision making, information sharing and system updates should be synchronised with the formal planning cycle. Where this is not feasible, informal practice will arise, usually out of necessity.
4. It is good practice to devolve the decision making to the level of execution ensuring that employees have the resources to make a good decision.

The latter two are used in the analysis provided as an example in section 6 below.

4.4 Design and apply a PSC audit

A PSC audit was developed to explore PSC design in six additional businesses and to test hypotheses. Each design rule could then be examined in detail in relation to the consortium businesses and the additional audited businesses. However, with the limited number of businesses involved there is no intention to derive absolute rules – the intention was to highlight design rules that could potentially support the identification and assessment of PSC design choices for which there was some empirical evidence.

5 RESULTS FROM ANALYSIS

Some of the key findings that have been incorporated into the Toolkit are described below.

Physical and policy characteristics of the operation influence options for PSC architecture:

- The physical organisation of the manufacturing facilities impacts on preferred PSC levels and interactions.
- The type of production (e.g. flow line, job shop etc...) impacts on the ability to devolve scheduling and resource management responsibility to production personnel.

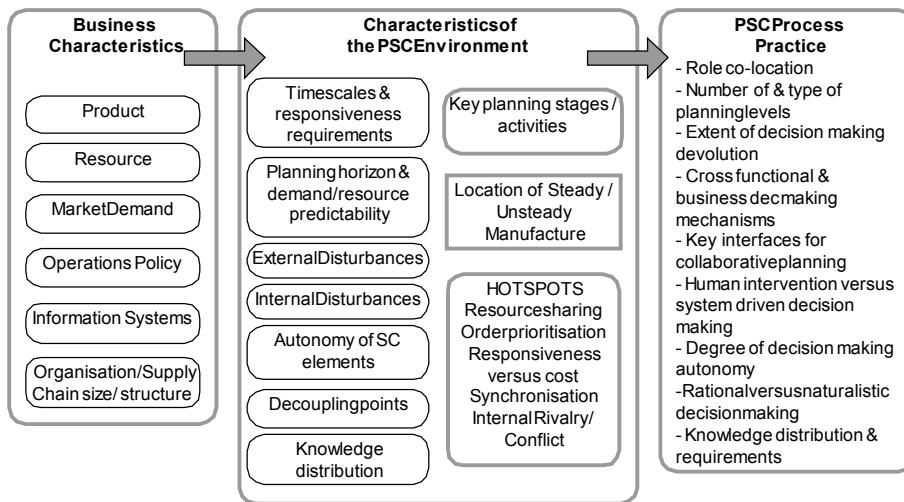


Figure 2: The 3 Stage Framework

- The policies supporting demand and capacity management affect preferred levels and forms of interfacing between functions – this knocks on to co-location and role integration options for these functions.

The business environment also impacts on PSC choices as do the characteristics of the events that trigger decisions and the nature of the decisions themselves:

- The specialisation of departments and therefore distribution of knowledge across the organisation affects the PSC decision making processes and the mechanisms that support them.
- As well as the distribution of knowledge, preferred knowledge integration mechanisms (through formal or informal meetings or network interaction, by instruction or objective setting) depend on the time period over which decisions need to be reached.
- The extent to which PSC decisions can be automated and the role of information systems is dependent on both the tacit content and the variability of inputs to decisions. Opportunities to automate can be established using GRAI net analysis.

Figure 3 shows the format of the individual decision analysis sheet used in the Toolkit to examine decision inputs.

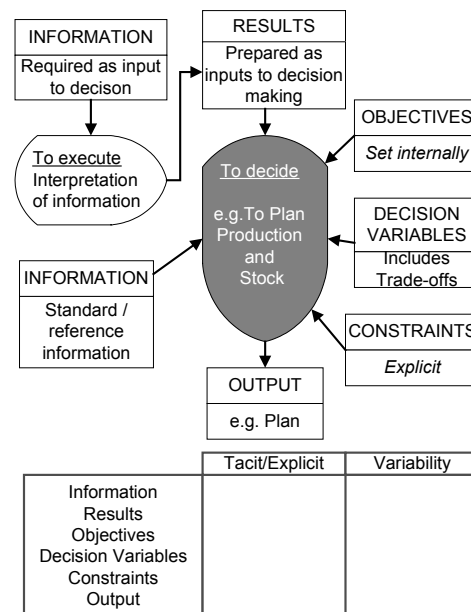


Figure 3: Decision analysis sheet

6 THE TOOLKIT

6.1 Development and description

The Toolkit is a combination of the audit tool and an analysis package designed to apply the design rules. It incorporates modified GRAI modelling techniques for analysis (e.g. Figure 3), other diagrammatic representations for visualisation and analysis, as well as tables and grids (e.g. Figure 5).

The Toolkit analysis process is shown below in Figure 4.

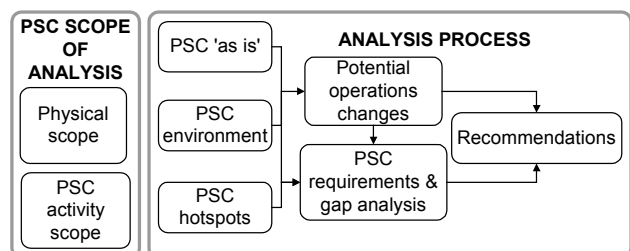


Figure 4: Toolkit analysis process.

The analysis is built up from a series of inter-related worksheets that audit and analyse data from the company. The worksheets play a crucial role in the analysis and re-design process.

In the section PSC 'as is', the worksheets capture, describe and in some cases model:

- The manufacturing operation 'as is' in terms of the configuration of the facilities, the layout of the processes and the classification of the production operation (e.g. M.T.O – line batch production).
- The operation 'as is' in relation to operations policies (e.g. whether to manage, chase and/or smooth demand), information systems and practices such as for fast tracking work.
- PSC 'as is' in terms of its organisation and practices; PSC levels, authority, roles and performance metrics, the form of decision making, and the distribution of relevant PSC knowledge.

In the section PSC environment, characteristics of the decision making environment are audited and described. These include:

- Disturbances to production and plan.
- Responsiveness and trade-off issues, and associated requirements.
- Decision making domain (whether relevant knowledge is held locally or distributed across the organisation).

In the PSC 'hotspots' section the PSC activities that are most difficult to manage are identified and described.

The subsequent sections entitled 'PSC requirements and gap analysis' and 'potential operations changes' provide the re-design analysis, identifying opportunities for change.

From a staged analysis of the manufacturing facility structure, the operations policies, the forms of demand and the trade-off requirements, the decision 'hotspots' specific to the business and the PSC 'as is' worksheet, the analysis phase identifies options for improvement which are then presented as recommendations. In addition to this, the application of the toolkit also considers changes at the operations level that could simplify PSC processes such as facility reorganisation or policy changes on managing demand.

6.2 Results and Toolkit Evaluation

In order to evaluate the Toolkit further it was recently trialed at a new business.

The Bakery business that took part consisted of one autonomous manufacturing unit with few supply issues. This business makes retail food products to order on a daily basis. The PSC architecture supporting this operation was relatively straight forward. However, a new MRP II information system had been introduced and there were concerns that old functional demarcations and practices were inappropriate. To address the business needs, as well as that of the research, the researcher selected the most relevant aspects of the Toolkit to apply to the business. The questions asked focused on establishing appropriate roles for people and systems and where it was necessary to improve cross functional interfaces to reduce the effect of functional silos. To achieve this a sub-set of the Toolkit worksheets was applied in earnest.

The analysis achieved the following:

- Confirmation of 'good practice' – e.g. that scheduling should be remote from the shop floor, whereas labour management is best devolved to production in order to be highly responsive, based on the production category (batch flow line), operations policies (MTO, same day assembly and to 'chase demand' achieved through flexing labour).

- Recommendations on roles and interfaces between functions – e.g. the role of scheduler and supply 'call-off', though currently separate, should be integrated to achieve the required speed of response. This was particularly the case as demand changes take place more frequently than the planning / scheduling cycle time and therefore cannot be incorporated within cycle.
- Identification of a major PSC 'hotspot' caused by the routine receipt of late changes to order quantities from the key customer. The Toolkit recommends on the relevant worksheet that either the planning cycle time is reduced or that the 'event' is brought into the system cycle time. This leads to the recommendation that the business focuses on finding a way to change its customer's behaviour. Figure 5 shows the form of the matrix used in this analysis.

Improving decision making		
Knowledge distribution	Event timing where $T_e = \text{event time}$ $T_p = \text{planning cycle time}$	
	$T_e > T_p$	$T_e < T_p$
Broad	Co-locate decision makers Integrate roles	Apply a combination of approaches
Focused	IDEAL	Bring event into planning cycle Reduce planning cycle time

Figure 5. Matrix analysis

7 DISCUSSION AND CONCLUSION

There are a number of different scenarios in which the Toolkit can be applied:

- Where order fulfilment performance needs to be improved substantially to remain competitive.
- Where restructuring has or is taking place within an organisation impinging on PSC and managers need to have improved visibility of PSC to identify key activities and human inputs.
- Where the implications of initiatives in manufacturing (such as 'going lean') create a need to review PSC.
- Where information systems (IS) are being implemented and appropriate structures and roles need to be established.

The case study in 6.2 focused on the latter scenario.

In this instance the PSC re-design Toolkit performed well. It was both effective and efficient providing in-depth PSC analysis to identify PSC re-design opportunities.

In terms of usability, the Toolkit presents a challenge as the analysis process is quite complex and may, therefore, appear quite formidable to an industrial user.

Ways to simplify the analysis are being developed. One approach is to simplify the process by identifying for the user the most relevant standard worksheets and routes through the analysis based on the application. The route presented to the user will be dependent on the questions being addressed by the business and the nature and complexity of the business itself. These standard routes are currently being identified and defined for incorporation into the Toolkit.

Modified to a level where a 'trained practitioner' could carry out an audit and apply the analysis to a business, it is intended that the Toolkit will be used as a consultancy tool to support PSC re-design in manufacturing businesses in an effective manner.

8 ACKNOWLEDGMENTS

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