PERGAMON

Omega 28 (2000) 277–292

omega
The International Journal
of Management Science

www.elsevier.com/locate/orms

TQM and BPR: lessons for maintenance management

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Received 1 June 1998; accepted 1 July 1999

Abstract

Competitive pressures on manufacturing organisations have obliged them to look at all improvement possibilities. Among the most popular and well-documented change interventions have been total quality management (TQM) and business process reengineering (BPR). As the management of physical assets now accounts for a rapidly increasing share of operational costs, greater attention is being directed to maintenance thinking. Two maintenance interventions — reliability-centred maintenance (RCM) and total productive maintenance (TPM) — have seen significant industrial application over the last decade. It is the purpose of this paper to apply the general approach of Meredith in an earlier paper to analyse the implementation of these with reference to the TQM, BPR and other change intervention literature and to assess the extent to which the maintenance implementation follows the path of other interventions. Four postulates relating to the implementation of new maintenance systems are analysed: the significance of a prescriptive methodology, quantification of objectives, managerial attitudes, and the importance of not appending maintenance initiatives to existing operations practices. This will facilitate a critical assessment of the potential for and implications of RCM and TPM intervention and thus contribute to the development of the maintenance management field.

Keywords: TQM; BPR; Maintenance; Implementation

1. Introduction

Companies are continually seeking new management interventions to improve their operations. Among these, TQM and BPR have been the subject of much practitioner and academic debate. Claims and counter-claims persist as to their effectiveness, and what has gone right and wrong in their implementation. Impressive reports of vast cost reductions and quality improvements are countered by scepticism and refutation. The same comments could be made about most other management innovations and change programmes. One functional discipline that has been rather neglected is the management of physical assets [3]. Two maintenance approaches have been developed and expanded in the last decade, and it is the purpose of this paper to consider some of the evidence of how reliability-centred maintenance (RCM) and total productive maintenance (TPM) are faring. As academic and critical practitioner maintenance management literature is limited, the exploratory study described in this paper leans on the theory and practice of TQM, BPR and other interventions. In so doing, it considers factors which are conducive to or hamper their successful implementation, assesses whether these can be

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0305-0483/00/$ - see front matter
PII: S0305-0483(99)00043-2

extended to a maintenance situation, and shows how managers implementing RCM and TPM can benefit from the findings of the study.

The research follows the approach of Meredith [57] who studies a number of postulates proposed from a review of the literature pertaining to the implementation of advanced technologies. We analyse four case studies with a view to establishing the validity of the postulates. Our postulates are derived from the TQM, BPR, JIT and other literature relating to the implementation of new technologies and systems. Having implemented TQM or BPR or both, the case organisations could relate these experiences with their maintenance encounters. Further, TQM and, to a lesser extent, BPR have been widely used in industry. As such, when considering the generalisability of the study, many organisations contemplating a new maintenance approach will readily be able to link maintenance implementational issues to TQM and BPR. Our choice of these interventions has parallels with the study by Flynn et al. [30] of the 'mutually supportive' nature of TQM and JIT. Through 'analytical generalisation' [93] the cases are used to assess the extent to which these factors apply to maintenance.

Section 2 contains a review of RCM and TPM in a managerial context, followed by a description of the case studies. Each postulate is presented with an explanation of the RCM and TPM experiences in the case organisations, and a discussion of the literature associated with it. We then compare the implementation of RCM and TPM, and make a series of prescriptive recommendations for managers on maintenance implementation. Finally we consider the limitations of the study and suggest areas for future research.

2. RCM and TPM in a managerial context

Manufacturing organisations have been compelled to look at their maintenance function for several reasons: increased competition has demanded strict cost control, with maintenance accounting for an increasing share of operational costs [65]; automated facilities require higher availability and reliability from plant and equipment; safety and environmental disasters are increasingly attributable to equipment failure; a reassessment of maintenance practices has been instigated by fundamental changes in the understanding of equipment failure [60,75]. Powerful proponents are selling RCM and TPM: the forceful persuasion behind RCM is frequently "this is the way the airline industry has been doing its maintenance for years" [64], while TPM is sold as the way Toyota and other successful Japanese companies do their maintenance [91].

RCM is a methodology where functionality of equipment, through a failure mode and effects analysis, and failure consequence evaluation, is used to determine appropriate maintenance tasks and the intervals at which these should be carried out. TPM provides a maintenance plan for the life of equipment through the elimination of the 'six big losses' [63]. Brief descriptions of RCM and TPM are given in Appendix A. The first problem in researching these concepts is to determine whether definitive, generally acceptable versions of RCM and TPM exist. The text of the originators of RCM [64] was written exclusively for the airline industry, but practitioner books [60,75] on the subject for industrial application have kept close to the generic version[1]. This is therefore the application presented here. Consultants and individual practitioners have produced their own variants, but these do not seem to have wide application. The acknowledged TPM expert is Nakajima, so the description in Appendix A is essentially taken from Nakajima [62,63], with additional material from Willmott [91].

Management commitment, appropriate support systems and effectively managing resistance to change are necessary for success in any management intervention (see for example, [24,57,64]) and apply as much to TQM and BPR as to maintenance. Much of the TPM philosophy is directed at addressing these conditions. There are other factors which pertain directly to maintenance: knowledge of machine capabilities, a thorough understanding of the production process and a high level of production competence are essential before maintenance requirements can be determined [13,29,44,60]. These are considered in the functional analysis of RCM. Improving performance remains an important task of maintenance [6,8], and with greater emphasis on functionality, the task of maintenance now becomes that of ensuring such functionality [34], rather than simply preventing failures. The basic types of maintenance have been extended from preventive, predictive and corrective to include detective maintenance[2] [60], which encompasses the developing technology for the maintenance of protective systems.

[1] A doomed attempt at a British Standard for RCM was made in 1994 (Document 94/408162); various versions have been developed, inter alia, by the US Defense Department, the Royal Navy, the Royal Air Force and Electricité de France. These have been adapted specifically to meet the requirements of those sectors.

[2] Preventive maintenance implies overhauls/rework or replacement at regular intervals; predictive maintenance refers to action which predicts failure (also referred to as condition-based maintenance); proactive maintenance is a generic term encompassing predictive and preventive maintenance; corrective maintenance means repair once failure has occurred; detective maintenance is a functional check, frequently of a protective system, to establish whether it is still working.

Table 1
Details of the case organisations

Company Rfood (RCM — food)	Company Rpharm (RCM — pharmaceutical)	Company Tfood (TPM — food)	Company Tchem (TPM — chemicals)
Quality had been addressed by an earlier TQM exercise; the objective of RCM was to decrease maintenance costs and improve plant availability; further, scheduled maintenance was to reduce by 25%	RCM was to provide a credible set of maintenance procedures to reduce costly breakdowns; poor equipment performance was adversely affecting the strict company product quality standards (A marginally successful TQM programme had suggested maintenance as a cause of quality problems)	TPM was to be incorporated into basic company philosophy to change maintenance by merging maintenance and operating staff; by operating in groups, managers promised a significant degree of empowerment, as an extension of TQM	TPM was the method of introducing TQM to maintenance; production and maintenance functions were brought together, under a policy of upgrading operator skills and multiskilling of craftsmen
Access was granted to the RCM worksheets whereon the RCM functional and decision analyses are recorded	All staff to be involved with RCM were trained and plans for meetings and auditing activities were strictly followed; nevertheless the RCM exercise took much longer than expected, mainly because knowledge of the production process (mixtures, processing times, performance standards, etc.) was lacking; process experts and management were often not able to furnish such information	Objectives were lower maintenance costs, a reduction in breakdowns and greater efficiency	Training of groups was undertaken by internal consultants on an informal basis with periodic visits during the TPM exercise; early discussions determined which maintenance tasks could be done by operators; these were not performed until remuneration was adjusted for increased operator responsibilities
Eighty people who would be involved in the RCM process were trained, over a period of two months; two facilitators were chosen to lead the RCM review groups, each of which consisted of a supervisor, two operators, a mechanical craftsman and on occasion an instrumentation/electrical expert and a process/technical specialist	The plan was to analyse nine major items of equipment (450 man-hours) in an elapsed time of 6 months; eight items were completed in 700 h in eight months	Nakajima's approach [63] was followed by creating a TPM master plan, establishing autonomous groups of operators, refining maintenance by maintainability improvement and reducing start-up problems	The plan was to complete one production line in 6 weeks, but nothing transpired for some 3 months while job demarcations were resolved
The RCM methodology in Appendix A was followed in 2 areas of the plant requiring some 600 man-hours over 4 months (analyses of other areas did not commence as a decision was awaited concerning the cost-benefit of RCM); after 3 months of inaction, the results of the RCM analyses were formalised by revising operating procedures, writing new maintenance schedules and authorising suggested plant and process redesigns; previously unknown protective systems were discovered and maintenance policies formulated for these	The greatest benefit was reported to be the amount learnt by team members about the process and equipment; most of the previous preventive maintenance tasks were replaced by condition-based tasks: a revision of product quality checks triggered additional maintenance intervention	Designated operators and craftsmen were trained; groups began with improved cleaning, lubrication, inspection, studying areas with common defects; all areas covered in 4 months; no records kept of number of man-hours spent on TPM, as this was done during normal operations, and process was intended to be on-going; teams established to study reliability and maintainability levels, through more advanced analyses; proposals made for revision of existing maintenance procedures and for implementation of new maintenance tasks and a maintenance information system; after a year, TPM was said to be 'firmly established', although few measurable results were evident	No systems for measurement were in place so no improvements in plant availability and performance were evident; after six months, some behaviour change was apparent with operators doing simple repair tasks; minor adjustments were made to existing schedules but TPM was accepted under duress and interviews revealed that the attitudes at operator and craftsman level were negative
Fifteen interviews were held: operations director, two area managers, four line supervisors, two facilitators, one process engineer, three operators and two craftsmen	Twelve interviews were held: factory manager, maintenance manager, three line supervisors, two process specialists, two operators and three craftsmen	Twelve interviews: production manager, three centre managers, four line managers/supervisors, one tech specialist and three operators	Eleven interviews were held: production manager, four production shift supervisors, four operators, two craftsmen.

Table 2
Case organisations' initial ranking of barriers in implementing maintenance systems[a]

Problem areas and obstacles	Rfood	Rpharm	Tfood	Tchem	Postulate
Don't know how to start			2	1	1
Insufficient guidance on procedures/how to continue			1	2	1
Inadequate training and familiarisation			10	6	1
No quantifiable objectives set	9				2
No ways to measure outcomes	10	8	8	10	2
Lack of time to complete all analyses required	3	5	9		3
Fear of disruption to production/operations	5	4	5	8	3
Lack of top management support	4	3	4	3	3
Lack of history/data	2	2			3
Lack of plant and process knowledge	1	1	3		3
Maintenance perceived as part of TQM	7	6	6	4	4
RCM/TPM used for empowerment	6	7		7	4
Other systems not adapted to support RCM/TPM		9		9	4
RCM/TPM used to introduce other (hidden) agendas	8	10	7	5	4

[a] 1 = ranked most important, 10 = ranked least important.

Faced with these issues as well as a host of technical challenges such as condition monitoring, reliability and operability studies, computer design and information systems, maintenance managers have adopted interventions such as RCM and TPM to provide a structure for dealing with these and the human dimension.

3. The case organisations

Four organisations were selected for this study. Two companies (Rfood having introduced RCM and Tfood having chosen TPM) are divisions of UK food manufacturers that were confronted by competitive pressures to reduce costs. These organisations had 'implemented TQM' a few years previously (with little tangible success) and were seeking further ways of improvement. Maintenance was selected as one discipline which had not been greatly affected by TQM. The third company, Rpharm is a pharmaceutical manufacturer and the fourth, Tchem, is a small volume, specialised industrial chemical manufacturer. These had respectively embarked on RCM and TPM programmes. In addition to introducing TQM in its manufacturing plant, Rpharm had 'reengineered' large parts of its operations over the past 3 years, while Tchem, in the words of the maintenance manager, had introduced TPM "as the TQM of maintenance". These organisations were chosen because of broadly comparable elements in their production and packaging systems, and because of their experiences with TQM and BPR. Our investigation in the case organisations started some 18 months after the companies had commenced with their new maintenance systems. The research was conducted over a period of 4 months.

The organisations permitted us to interview their personnel at all levels. Initial one-on-one interviews sought respondents' opinions on factors (described in the Section 4) which detracted from RCM or TPM implementation. Participants were invited to mention problems in confidence, as some were concerned that criticisms of management would be attributed to them. These concerns were grouped into broader categories (the postulates to be tested), and formed the bases for subsequent interviews. The positions held by the respondents interviewed and details of the cases are contained in Table 1.

Some (incomplete) quantitative data was collected for plant availability, and planned and unplanned downtime for before-and-after comparisons. It was not possible to cost at machine level, nor had sufficient time elapsed to assess major changes arising from revised time-based maintenance policies.

4. Postulates for new systems implementation

This paper seeks to ground the study of maintenance management implementation in the wider context of change programmes by ascertaining whether managers can establish 'crucial concepts' [73] for implementation and learn from those who have introduced new systems. The choice of postulates for the research is based on three considerations. Firstly, during initial discussions with managers, supervisors and operators in the case organisations, they were asked to list the main problems and obstacles experienced in their maintenance implementation, and to rank the top 10 in order of importance. The modes of the individual rankings for each company are shown in Table 2.

Secondly, in following Meredith's [57] approach we are influenced by the promoters, driving forces and critical factors found in the practitioner and academic literature relating to the implementation of new technologies and systems [5,45,53,58,68], although we shall not repeat these here. Thirdly, it was necessary to select a 'manageable set of categories' [88], permitting us to consider each in some detail. We have grouped the factors into four broad postulates, as shown in the right hand column of Table 2. The postulates themselves were not challenged by participants, although questions were raised about the apparent omission of issues mentioned in the initial interviews. Some of these had been incorporated under a different postulate, while points mentioned by only one or two respondents were indeed excluded.

The postulates necessarily lack in conceptual richness as their main function is to focus managers' minds. While they may seem somewhat trivial at first, the postulates are based on the literature of critical success factors and common-sense interpretations of the implementation of RCM and TPM. In each case the literature on TQM, BPR and other interventions helps to contextualise the postulates, thereby making managers aware of issues which may not be immediately obvious. The experiences of the case organisations in relation to each postulate are described, followed by reference to the literature.

4.1. Postulate 1: a standard prescriptive methodology facilitates the implementation of maintenance systems

Comments about TPM in the case organisations were typically "What precisely is TPM?" (Tfood line manager), "We know the theory, but how do we start implementing it?" (Tchem operator) and "We cannot get to grips with exactly what we are supposed to be doing with TPM" (Tchem shift supervisor). While people readily related to the 'six big losses', they sought a methodology to address these. Although initial training had been useful in explaining the overall concept, it did not lay down a prescriptive implementation path, and much was left to the line managers' own initiatives. In order to speed up the exercise, TPM autonomous groups found they could curtail steps in the TPM process by selectively using, or indeed not applying, some of the industrial engineering-type techniques suggested by Nakajima [62].

Rfood and Rpharm were able to follow the structured RCM information analysis and decision process without difficulty, although both organisations commented that failure data was lacking. This generally prompted criticism of their maintenance management information systems, rather than of RCM.

Several authors have asked whether TQM and BPR have identifiable conceptual cores and precisely what they encompass [16,40,77]. Although extensive studies have tested factors which affect the implementation and success of TQM, there is no established methodology or industry standard for introducing TQM [9,36,37,56,76,82]. TQM does provide a structure, for example, for the application of quality techniques such as SPC [72]. Proponents identify a number of core elements, such as customer focus through data gathering and processing; emphasis on participation, empowerment and teamwork; and continuous improvement [2,27,49,90]. Definitions of BPR are equally problematic [10,19]. The lack of standardisation in introducing BPR may be seen as an advantage, as this permits organisations to implement it, evaluate it, and measure its outcomes in a number of ways [28,38,39,78]. TQM and BPR encompass both mechanistic and organismic processes, with the attraction that managers are enticed by fashionable yet somewhat indeterminate concepts, under whose guise almost any management intervention can be implemented, and to which credit can easily be attributed. It is ironic that concepts so openly and extensively in the public domain are ill-defined to the extent that managers can use them for their own ends, without fear of being challenged or contradicted [11,46,47].

Thus, part of the popular success of generic change approaches such as TQM and BPR may be explained by their inherent ambiguity. They appeal to a wide audience because everyone can find something of value in the various approaches making up these constructs. However, popular success does not equate to operational success. Consultants have benefited from the popularity of the programmes, but not so the individual within the organisation who is charged with 'making it happen'. A lack of prescription may even be helpful to obtain the commitment of various constituencies inside the organisation "in order to legitimize all sorts of measures and changes in the name of a self-evident good" [92, p. 1]. However, this is a recipe for confusion and disenchantment.

Research findings from other interventions indicate that formal implementation procedures have favourably influenced successful just-in-time projects, although a definition of what JIT entails has proved elusive [70,83,86,87]. MRP implementations also require high degrees of formalised implementation [51]. In some cases an ill-defined technology is used to standardise procedures in an attempt to ensure adherence to organisational disciplines [79].

From the case study experiences, it is argued that managers should develop a coherent, plausible and legitimate discourse for RCM and TPM that will provide actors at all levels with distinctions, definitions and understanding. Managers must be active shapers, especially in the case of TPM, setting explicit agendas even when the literature provides no clear direction. Even after providing a prescriptive methodology (which to some extent must be made up in the case of TPM), managers must still remain sensitive to interpreting developments as systems and procedures come on-line in their organisations. For example, the group in Rpharm decided to check temperature gradients during mixing cycles in an attempt to study inconsistent insulation deterioration, whereupon the production manager instructed her operators to take additional product samples which would reveal the effects of abnormal temperatures. This development arising out of maintenance checks was seen by the production manager as a sound basis for revising operating procedures.

4.2. Postulate 2: objectives and outcomes from maintenance systems should be quantified

The debate concerning the outcomes of new interventions invariably turns to technical and measurable issues such as costs, benefits, tangible improvements and monetary savings [40,89,92]. The literature refers to the lack of recognition given to performance measurements [12,62] and accounting systems which fail to meet the information needs generated by a new intervention [21,80,85]. Moreover, there is a great diversity of opinion as to what constitutes success and how this should be measured [70].

All case organisations were disappointed with the lack of measurable outcomes, and admitted that their objectives had been ambiguous and unrealistic. There was only anecdotal evidence of improvements in maintenance. Rfood estimated that the reduction in scheduled maintenance through RCM had achieved their targeted figure of 25%. Rfood had attempted some benchmarking by contacting other food manufacturers that had implemented RCM, but the only comparable measure available was the percentage reduction in schedules: while this was broadly in line with other organisations, this proves little in terms of the "success" of RCM. Records of plant utilisation in Rpharm had increased by a few percentage points to 76%, but this was more a reflection of production demand, than a direct measurement of availability. Although lower maintenance costs were a key objective of Rfood, no attempt had been made to calculate these, nor was it possible to assess if revised maintenance policies were themselves cost-effective.

The production manager in Tchem granted that the plant was cleaner, lubrication was better, several design problems had been identified, and operators had been allocated additional maintenance tasks[3], but the TPM promise of zero defects was a long way off. Beyond these instances Tchem's production manager was frustrated that there was little to show from TPM (particularly after an unsuccessful TQM exercise). Tchem supervisors felt that TPM had advanced the merging of production and maintenance into one function. Tfood could not quantify improvements, but a qualitative assessment pointed to a reduction in scheduled maintenance. While some Tfood managers felt that empowerment had been achieved, with greater commitment to the elimination of defects, supervisors were less convinced by claims of improvements in availability and reduced costs, as the information for such measurements was not available.

Supervisors in Rpharm asserted that publicised before-and-after comparisons were of limited value, as they were used by managers to promote RCM, rather than to provide constructive evaluation thereof. Such reasoning is reminiscent of the BPR targets set by accountants [14] where BPR is used as the mechanism to arrive 'scientifically' or 'objectively' at such figures. The indeterminate maintenance outcomes are similar to those found with TQM and BPR [40], JIT [69,70] and MRP [51].

BPR objectives are often ambiguous and the lack of established effectiveness measures renders evaluation difficult [4,23]. Indicators of success may include "changes in leadership behaviour, style and language, quality of communication and the degree of quality awareness" [76]. The BPR literature contains conflicting reports of successes and failures: surveys of reengineering projects that consistently fall short of their expectations are countered by accounts of increased productivity, and appropriate and effective downsizing [39,41].

While desired outcomes of TQM take the form of fewer defects, better service, cost savings, reductions in the workforce and higher operating efficiency [40,41,76], actual outcomes may be nebulous and indeterminate. Some surveys contain glowing accounts of TQM successes [31,33]. Contrary findings of limited success or failures are well documented [26]. Without specifying precise outputs, there is confusion as to what change programmes are really about. Thus, TQM may be perceived as the process, the training programmes, the meetings and the systems, and even the company publicity and progress reports; sight is lost of what the end goal is [19].

A question raised by this discussion is why an observation as obvious as this postulate should prove so difficult to operationalise. The answer lies in the political dimension of measurement. Key participants in the

[3] The extent to which operators performed maintenance tasks was determined by their ability. Several had previously been fitters, and with rationalisation and downsizing, some operators had been made redundant, and craftsmen transferred to operating and maintaining the lines.

process have an elementary interest in measuring certain things in certain ways (which will make them look good) while some seek other ways to measure, or not to measure at all (for fear of their being exposed). Managers cannot consider 'measurement' as a purely technical or neutral concept. They should be aware that the measurement must be viewed in the context of on-going struggles in the organisation, around control, power, authority and consent. The example in Rpharm at the end of Postulate 1 (Section 4.1) where temperature measurements were formalised, show how ties were built between the investigating group, operators, and insulation specialists, each with mutual interdependencies, and yet the manager, as the final arbiter of what remedial action was to be taken, retained her power base. Ironically, she demonstrated greater commitment to RCM than her maintenance counterpart by encouraging an investigative process whereon she was able to improve performance in her own production department. This illustrates both the technical and political attributes of measurement.

4.3. Postulate 3: successful implementation of maintenance interventions depends on positive managerial attitudes and action at senior levels

Prior to our study, group members had had no formal opportunity to voice their opinions on RCM and TPM. By drawing RCM groups from different disciplines, management expected participation and broad commitment. Members found group discussion useful, but were frustrated by managerial intransigence (such as not implementing, or even reacting to, recommendations made by the groups). Group members repeatedly commented that senior management had initiated the processes whereafter interest waned.

RCM tasks were only implemented in Rfood when a line supervisor emerged as a champion [22,50,57] and took responsibility without recourse to management. Managers in Rpharm and Rfood were concerned with what they saw as a cumbersome and time consuming process. When facilitators pointed out that RCM demands detailed functional knowledge of equipment and process, which was frequently deficient, management in Rfood stated that plausible assumptions should be made to speed up the analyses. The RCM teams complained that management did not understand the process, and made suggestions which clearly violated the RCM decision process, merely for the sake of expediency: this was management interference, not management support. Rfood's management refused to allow tests to be carried out on machines in order to determine their true functional capabilities.

Tfood's management frequently cancelled meetings. The suspension for several months of maintenance training for Tchem's operators was not explained. Teams in Tfood were frustrated by the reluctance of managers to implement suggested redesign projects. TPM operators indicated that colleagues not in groups could not be relied upon to implement recommendations imposed by a system in which they had played no part. Managers in all cases were criticised for not using their influence to ensure a response to group recommendations.

Since planning and implementation of the recommendations do not form part of the RCM functional analysis and decision process, nor are they specifically mentioned in the TPM steps, this vital stage was neglected: no one had been allocated responsibility for taking the process further. This illustrates inconsistency [15,17,32] and an incomplete sequence of employee involvement from managerial initiation to employee commitment [54].

Drucker et al. [25] speak of "widespread disenchantment with the once beloved TQM". Of the reasons for this in a TQM context as well as other new systems implementation, a lack of management support appears in almost every study [1,15,18,57,61]. Management attitudes and actions are intuitively obvious factors affecting intervention outcomes, and pervade implementational issues in various guises, such as management commitment, leadership, setting up support systems and policies [71,74,80]. Managers increasingly perceive their role as one of setting the process in motion, creating opportunities and providing facilities and training, but they see the intervention itself as something for others in the organisation [50]. Increasingly, management should encourage the process of knowledge acquisition, through "legitimizing familiarisation activities" [22, p. 161]. The degree to which implementation is successful goes beyond training and education [66], to knowledge of products, processes and quality standards, and depends on the ability of the organisation to learn [45], with empowerment symbolising the "learning mindset approach... the company tackles quality by becoming a *learning organization*" [76, p. 82].

Again, we aim to move beyond these obvious observations and explore the underlying reasons for a lack of consistent action at senior levels. We would suggest that middle managers and senior managers are playing different 'games'. For senior managers, management systems like RCM and TPM are labels which signify to organisational stakeholders both the goals which senior managers should pursue as well as the means by which the goals may be attained. In order to retain stakeholder support and maintain their legitimacy, senior managers must be seen to be using such techniques. This view is reinforced by Meyer and Rowan [59, p. 340]: "Organizations are driven to incorporate the practices and procedures defined by prevailing rationalized concepts of organizational work and institutionalized in society. Organizations that do so increase their legitimacy and their survival prospects, independent of the immediate efficacy of the acquired practices and procedures"[4].

Whether the implementation of RCM and TPM actually achieves any measurable improvements is seen as a bonus from this perspective. This is not to say that managers do not care about operational and technical matters, but by virtue of their positions, senior managers will be more preoccupied with and attuned to such institutional pressures. In the extreme case, the adoption of a maintenance system may not be linked to internal needs at all. Institutional pressures may also operate at lower levels where managers implement systems that are considered by the professional community to be up-to-date and effective, and which are seen to represent progressive management. The issue is more one of perception (the institutional dimension where managers are seen to have introduced RCM or TPM) than of substance (the technical component relating to what they have derived, as discussed in Postulate 2, Section 4.2).

4.4. Postulate 4: successful maintenance intervention cannot simply be an adjunct to existing operations practices

Experiences in the RCM companies suggest that provided a clear methodology initiates the process and elicits the support of operations and maintenance staff, new ways of doing maintenance emerge. Practices thus adopted give rise to new sets of organisational understandings, which gradually gain ascendancy, become further refined in the process, and ultimately assist in spreading the new practices further (this sequence of events follows that of Tsoukas [84]). Initiating RCM presented no problems, as review groups had precise rules to follow. Participants were persuaded of the merits of the RCM approach at least to the extent that they proceeded with the RCM analyses, and a new maintenance system was established.

New ways of thinking about and undertaking maintenance included abandoning annual shutdowns in Rpharm and dispensing with criticality as the basis for determining the frequency of condition monitoring in both RCM organisations. The latter led engineers in Rfood to set up procedures to obtain lead times to failure through investigations (the "refinement" suggested by Tsoukas [84]). Supervisors in Rpharm were reluctant to follow management's suggestions that a largely unsuccessful SPC initiative should be revitalised as a way of determining lead time to failure: they felt that SPC had failed. There was resentment in Rfood that RCM was presented as a way of empowering people (an adjunct to an existing company-wide empowerment initiative).

At the outset TPM was sold as "the TQM of maintenance" in Tchem despite a commonly encountered opinion that TQM had not been successful. Attitudes to TPM, as an 'adjunct' to TQM were not positive. The lack of a prescriptive methodology led to further frustrations with TPM. There were nevertheless instances where the new approach led to the new practices [84]: for example, upon recognising that their current policy of replacing seals on hydraulic equipment was not appropriate, Tchem instituted a programme to establish the life of hydraulic seals, which in turn led to an overall revision of the maintenance of hydraulic systems.

In going about these new practices, employees interact with other parts of the organisation and if other practices remain unchanged, the new rules and practices that RCM and TPM have introduced will be undermined. This was witnessed in Tfood where management continued to insist that maintenance be done while cleaning took place during a product changeover, even though there was no valid reason for doing maintenance at these (irregular) intervals: "maintenance must climb in while the line is down". TPM group members repeatedly stated that maintenance would not be improved if its frequency is based merely on operational convenience. Maintenance spares holding policies in Rfood were not adjusted to support the new maintenance tasks and intervals, so non-availability of spares rendered some of these impossible.

Managers should be sensitive to newly emerging meanings. There will always be an important asymmetry between rules-as-represented (such as in the initial RCM methodology) and the rules-as-guides-in-practice (how RCM groups make sense of their experiences). The latter are far richer, particularly when members recount their newly acquired understanding of equipment functionality ("I didn't know it worked like that" (Rpharm operator), or from an Rfood supervisor: "you cannot fix something if you don't know exactly how it works, how it goes wrong, and what happens then"). An RCM group in Rpharm spent 2 h discussing the effect of one failure mode of a large hydraulic system: which alarms sounded, which valves opened and closed and when, what was the final default position of the cylinders, what repair was necessary, what was the effect on production? The

[4] Several illustrations of this were encountered. Rfood, which as part of a corporate group was following other subsidiaries in introducing RCM. One of the forces driving Tfood to implement TPM was that it had established from a benchmarking exercise and trade journals that its competitors were claiming lower operating costs after their TPM implementation.

group acknowledged that no one had known how the system worked, and that determining functionality by following the RCM methodology had been an invaluable learning experience. Members of the teams in Rfood[5] and Rpharm maintained that the greatest benefit which they had derived from RCM so far was significantly increased knowledge of the plant and the process. This led, in an unstructured way, to further discussion of how other systems functioned.

Although managers should take a lead in the process by offering a firmly defined implementational methodology (Postulate 1, Section 4.1), they also need to be sufficiently flexible in engaging creatively in the emerging meanings associated with the dynamic unfolding of concrete interactions resulting from RCM and TPM over time. This implies a rethinking of other organisational processes that affect or are affected by maintenance functions. Often the reverse takes place: an ambiguous process is set in motion and as people become disenchanted or even resist the implementation of what they consider to be half-baked ideas and solutions, procedures are 'tightened-up' to regain control. This is a recipe for failure, as the TQM/BPR literature has shown [42,74,83]. Rfood group members did not understand the continuing need for an annual shutdown of each line, when the number of tasks requiring annual action had been decimated. TPM's recommendations of reduced maintenance in Tfood were countered by managers' quoting hygiene standards which (managers said) required that many existing maintenance tasks be retained.

As with RCM, TPM was seen as an extension of management's empowerment aims (perceived as a type of forced empowerment [81,88], driven by the underlying managerial agenda of embedding operator-maintenance and reducing costs), which had originated from a broad interpretation of TQM. Supervisors in both organisations commented that the reality was increased responsibility without commensurate autonomy [48][6]. Using RCM and TPM as adjuncts to existing, or failed, initiatives did not enhance commitment: rather they were seen as a somewhat devious effort by management to resurrect these.

This is one of the problems which arises when the scope of an intervention is not bounded or understood. Boundaries and understanding pose a problem in that participants indulge in sob stories which blame the intervention for not being able to achieve a host of requirements. One Rpharm review group was disappointed that "RCM did not provide the failure data which we need to decide how often to maintain the plant". A group in Tchem criticised TPM for "not specifying which type of lubricant we should use in the gearboxes". Clearly, these examples illustrate a lack of understanding of what the process can deliver, but such comments also lead others to have reservations about the interventions themselves. The goals of the interventions are associated with other managerial initiatives. So, for example, TPM becomes an extension of management's empowerment aims; RCM evolves into a method of achieving lower maintenance costs, which is perceived to be management's real goal. This created an illusion of retrospective determinism: what was publicised as going to happen, had to happen (managers said maintenance would be better, so after implementation, maintenance was reported as having improved).

5. Some comparisons and lessons

Underpinning the contextualisation of the four postulates is the suggestion that managers must recognise the irreducible social dimensions of the RCM and TPM implementations, and the web of social relationships required to operationalise the postulates. Management must recognise that there is a need for group members to develop self-reflective and meaning-creating skills if the processes are to extend from a narrow interpretation of a defined methodology (where it exists) to a broader acceptance of the conceptual issues of maintenance management. RCM and TPM place managers in positions where they control individuals' thinking and behaviour. TPM's 'autonomous' groups are controlled through management structures established through the TPM development activities. The onus is on management to support the programmes (Postulate 3, Section 4.3) by creating the momentum and steering the process away from subsumption by the technique itself: RCM must be more than sheets of paper; TPM more than operator-performed maintenance.

Change programmes are context dependent [66], and just as the success of TQM and BPR can seldom be empirically proven, so in this study it is not possible to establish that RCM and TPM were categorically successful or otherwise. They brought about change, less through their inherent characteristics and more

[5] Managers in Rfood recounted how another subsidiary had used RCM exclusively as a training mechanism once it became evident how much plant and process knowledge was lacking. This was done through detailed descriptions of the functions of the equipment, through the failure mode and effect process, and onto a detailed discussion of the way in which items failed.

[6] Just-in-time studies show similar findings, where respondents report perceptions of high involvement and responsibility, but no authority [70].

Table 3
Summary of company perceptions of postulates

Postulate	Rfood	Rpharm	Tfood	Tchem	Overall RCM	Overall TPM	Overall TQM	Overall BPR
(1) Is there a standard maintenance implementation methodology?	yes	yes	no	no	yes — this facilitates implementation, as groups have a defined process to follow	no — lack of structure impedes implementation as too much is left to management and/or group discretion	no — literature shows there is no established methodology to implement TQM	no — literature shows no single way to implement BPR, so managers are free to specify processes
(2) Are RCM/TPM outcomes quantified/quantifiable?	no	no	no	no	no — no systems to measure outcomes; no quantification of results, except % reduction in schedules and fewer breakdowns; objectives not specified; human aspects of maintenance not mentioned	no — no systems to measure outcomes; no quantification of results; improvements perceived (cleaner plant, better lubrication); quantifiable objectives not specified; human aspects of maintenance not addressed	no — systems not in place to measure outcomes; no quantification of results; precise outputs are not specified	no — systems not in place to measure outcomes; little quantification of results; quantifiable objectives sometimes specified (such as reductions in workforce)
(3) Are senior managerial attitudes and actions important for successful implementation?	yes	yes	yes	yes	yes — on-going support for attendance at meetings lacking; management interference to speed up process; little effort to implement recommendations	yes — management abdication of process after initial enthusiasm; no management assistance with TPM process; little effort to implement recommendations	yes — lack of management support detracts from outcomes; management perceive process differently to operating staff (e.g. empowerment, responsibility, etc.)	yes — insufficient involvement, inability to overcome resistance, etc. diminish effectiveness of BPR; process often tried after others (such as TQM) have failed
(4) Can RCM/TPM be adjuncts to existing practices?	no	no	no	no	no — RCM should stand alone as a maintenance intervention, without tying it to other exercises such as empowerment, cost reduction or down-sizing; suspicion that RCM implemented for ulterior agenda	no — lack of definition meant that TPM is too easily extended to support other initiatives, such as maintainer-operator systems; feeling that this was the real agenda;this detracts from successful implementation as it blurs ideals of TPM	no — TQM has been used too widely as an all-embracing change mechanism including organisational transformation, sometimes to the detriment of quality itself	no — as a more radical process than TQM, BPR is often used as an extension to TQM, as a major change initiative. Sight is lost of true aims of reengineering

through the context in which they were applied. Participants in each company had remarkably similar comments about the lack of tangible benefits from their respective interventions (Postulate 2, Section 4.2). An area manager in Rfood suggested going beyond RCM and using TPM to address organisational issues and to encourage continuous improvement. The factory manager of Rpharm also considered the TPM option in order to think in a 'TQM way about maintenance'. A centre manager in Tfood was satisfied with the broad TPM maintenance thinking, but proposed that the company should go further than TPM and use RCM to provide answers to detailed questions (such as frequencies of tasks, which are not provided by TPM). A supervisor in Tchem also sought further specific guidance in maintenance task determination, through RCM. This 'beyond' thinking [19] is a common feature of the TQM and BPR literature, with BPR being seen as the natural successor to TQM and a further stepping stone in becoming a world class company [52]. The difference in maintenance management is that TPM and RCM may be seen as potentially complementary, rather than sequential (we say 'potentially' as this has yet to be investigated).

Table 3 summarises the case organisations' *perceptions* of the postulates from a maintenance perspective, and includes corresponding points from the TQM and BPR literature. Findings from the two RCM companies are almost identical, and likewise for the two TPM organisations. A comparison between RCM and TPM reveals differences in Postulate 1 (Section 4.1): RCM has a standard methodology, which assisted implementation; TPM, like TQM and BPR, does not. The other postulates show commonalities between RCM and TPM.

6. Implications for managers

In order to render the findings of the research useful to managers, this section addresses implementational issues associated with the postulates.

6.1. Postulate 1: need for clearly stated methodology

The RCM case companies reported no methodological difficulties as RCM has a precisely defined methodology. Making TPM more prescriptive requires a step down from the essential features described by Nakajima [63]. In particular, prescriptive sets of rules are needed for Nakajima's third feature: developing productive maintenance for the life of the equipment. TPM training provides TPM Master and Development Plans [63] and extensive descriptions of maintenance concepts. At a practical level, trainers and managers should provide instructions on how to structure the selection of maintenance tasks and how to determine maintenance intervals. Brainstorming possible causes of failure is inadequate: failure modes should relate to the inability to meet specific functional performance levels. Regarding intervals, it is not sufficient to say, for example, that machine conditions must be monitored 'periodically' [63, p. 57]; an explanation of the lead time to failure concept for determining inspection intervals is required.

6.2. Postulate 2: needed quantification of objectives and outcomes

This is not an issue of concern only to RCM and TPM, although it relates to Nakajima's first feature: maximising (and being able to measure) equipment effectiveness. The standard ways of doing this [63, p. 31] should be taken further in terms of equipment functionality. The first step in maintenance is to determine whether a system is inherently capable of meeting its desired delivery standards [60] and then to establish how machines can sustain required operating conditions. Maintenance is 'successful' if it can ensure equipment functionality under certain operating conditions: cost-effectiveness, ensuring adequate safety standards and so on [60]. It is not sufficient merely to say, without quantifying performance standards, that machines must operate at their 'full potential' [63, p. 94].

Once the measurement context has been established, the impetus for measuring is created in terms of measures such as availability, performance and quality. Frequently, the effectiveness of a maintenance programme is assessed in a before-and-after comparison of the number of schedules required. A more appropriate measure would be the number of man-hours of scheduled maintenance, or the costs of these man-hours. Comparisons of this nature are simple, and require no more than management directives to gather the information.

Another common objective is to reduce maintenance costs. Cost comparisons are required at machine level, which is usually a level or two lower than cost centre level in most organisations. A time period of years is also often required for cost comparisons, particularly if the lead time to failure and equipment life are several years. An important consideration requiring reasonably accurate data is the cost-effectiveness of proactive maintenance, which involves a comparison of the economics of prevention and failure. Managers must be aware that it is extremely difficult to quantify the costs and benefits of new maintenance interventions, that is to justify them on the basis of a cost/benefit analysis: in the short term, adequate information is rarely available for before-and-after comparisons; in the long term, it is seldom possible to ensure constancy of all variables.

6.3. Postulate 3: how management can better support the process

There are so many aspects to management support of new initiatives that we mention briefly those which were highlighted by the case organisations. The two criticisms mentioned most often were capricious support during the project and lack of follow-up on recommendations. This means dependably ensuring the availability of the best resources at all times, providing the systems for monitoring and retaining the data gathered, and acting on recommendations by RCM and TPM groups (which was tardy at best, and usually non-existent). Perceived managerial inconsistency and indifference had a strongly demotivating effect. Practical management strategies should involve building coalitions, creating dependencies; managers must be seen to be satisfying strategic contingencies, controlling decision premises and making preferences explicit, while keeping their own power implicit.

6.4. Postulate 4: maintenance interventions cannot be adjuncts to other initiatives

The expectation by management of transformation in their maintenance activities is an alluring and a desirable goal. Ideally this would mean total adherence to "the complete elimination of failures, defects and other negative phenomena" [62, p. 10]. Promises by management of transformation or empowerment will be met with scepticism for as long as there is a perception that the maintenance processes are surrogates for an underlying agenda, which is usually believed to be a reduction in costs and labour. The evidence shows that RCM and TPM are unlikely to produce radical and meaningful improvements in maintenance unless substantial effort is put into events beyond the meetings-and-worksheet-generation of RCM and the issues of operator-autonomous-maintenance in TPM.

While lack of methodology detracts from successful implementation, the issues raised previously regarding too narrow an interpretation of the interventions limit their application. Organisations may come nearer to meaningful change by debate and experiment, by self-reflection and meaning-creating skills [20], not by prescription. Assiduously following a maintenance recipe creates tunnel vision, and does not lead to broader thinking of how or if maintenance can truly be enhanced. Awareness and acknowledgement of institutional pressures open up a space for discussion and reflection. The interrelationships between new initiatives and existing practices require management recognition: independently functioning systems seldom yield the best long term results.

7. Limitations of the study and areas for further research

This study has several shortcomings which present areas for further investigation. Like all case-based research, the study presents limited conclusions derived from a small sample. There is considerable scope for surveying a larger number of organisations, in a wider range of industry sectors. We have only attempted to identify critical factors for maintenance initiatives; we have not measured the strength of their relationship with successful implementation [67]. Maintenance intervention can take months if not years to reveal any tangible results: this is particularly the case where frequency of measurement or the life of equipment is long, or when business cycles and intermittent activity may have an effect on equipment utilisation. This means that a longer term study is called for.

It is tempting to look at RCM and TPM as complementary: RCM has a prescribed methodology; TPM does not. In its prescription RCM may lose sight of broader issues; TPM is guided by higher level "essential features, zero breakdowns and zero defects". RCM requires an understanding of equipment and process; TPM involves operators in certain maintenance activities, and so on. A detailed comparison of RCM and TPM is beyond the scope of this paper. Imposing RCM on TPM, or vice versa, has been suggested as an appealing prospect (some respondents in the cases suggested this). This would require an extended study to provide a solid theoretical and practical research base for meaningful comparison.

8. Conclusion

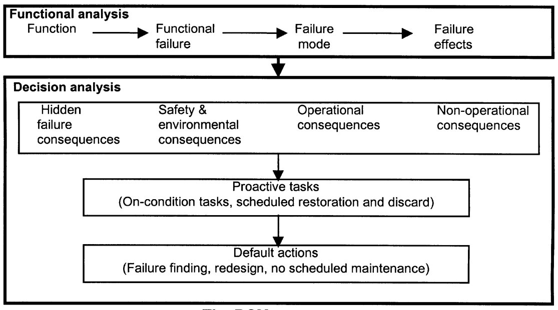
The case organisations that had earlier embarked on TQM and BPR did not find them to be successful. As part of their subsequent action they chose a maintenance intervention. Following some preliminary results which have not produced immediate answers and improvements, managers are already looking for the next programme. They should rather be looking at how their experiences with RCM or TPM can help them achieve a meaningful outcome. In the previous sections we have presented some ways of addressing these, but managers face a difficult task: they are being asked to perform and achieve in a context where often "they neither understand how their actions produce results, nor are able to influence the most volatile element in the organization — other people" [43, p. 171].

People in the case organisations will recall the inconsistencies between the assumptions that previous interventions espoused and their experiences with them: they will then compare RCM and TPM with these as a means of solving organisational problems, and be reminded of earlier attempts which were managerially conceived and which were largely unsuccessful [7]. Without a more sophisticated conceptualisation of what has been occurring with their maintenance programmes, it is likely that these will suffer the same fate as other initiatives: a mixture of partial successes and failures, and a continual, but potentially futile search for the next intervention. As a preliminary study, this paper has attempted to establish a set of success factors for RCM and TPM implementation, and to provide some guidance for their adoption.

Appendix A

Reliability-centred maintenance

RCM, initially developed in the civil aviation industry, is a structured approach to determining the maintenance requirements of physical assets in their operating context [60]. RCM establishes the functional requirements and desired performance standards of plant and equipment. By relating these to design and inherent reliability parameters, functional failure characteristics are determined, and for each of these, a failure mode and effects analysis (FMEA) is performed. The consequences of each failure fall into one of four categories: hidden consequences, safety or environmental consequences, operational and non-operational consequences. Following a process of decision logic [35,55,60,75], proactive intervention (on-condition tasks, scheduled restoration or discard) is considered which deals with failures according to strict applicability and effectiveness criteria. If the criteria for proactive tasks are not fulfilled, default tasks include failure finding (for hidden consequences), possible redesigns of equipment, changes in operating, maintenance and training procedures or no scheduled maintenance. The process as set out by Moubray [60] is summarised below.



The RCM process

The generic RCM developed by Nowlan and Heap [64] gives no indication of how a maintenance programme should be developed. The human dimension is thus not part of their underlying philosophy. A group approach is suggested by several authors [55,60] with participants, trained in RCM and led by a facilitator, representing the production and maintenance functions, and where necessary, appropriate technical and process specialists.

Total productive maintenance

The literature presents TPM as more of an amorphous concept than RCM, although five essential features are stipulated [63]:

1. maximising equipment effectiveness;
2. development of productive maintenance for the life of the equipment;
3. involvement of all disciplines (engineering, design, production and maintenance) in TPM;
4. active involvement of all employees and
5. promotion of TPM through motivation management: autonomous small group activities.

Nakajima [63] states that the first is achieved by "the complete elimination of failures, defects and other negative phenomena" (which is, of course, central to the Japanese zero-defects philosophy). He points to the fusing together of the traditional maintenance and production functions as acceptance that operators can be expected to perform simple maintenance tasks. The company-led small group activity, similar to the quality circle approach, is "consistent with Likert's Participative management model...". Overall efficiency, which includes economic efficiency, is achieved by "...minimizing costs of upkeep and maintaining optimal equipment conditions throughout the life of the equipment... by minimizing life cycle cost" [63, p. 10].

TPM establishes a maintenance plan for the entire life of equipment, by including maintenance prevention (MP: by which is understood maintenance-free design), preventive maintenance (PM) and maintainability improvement (MI: repair or modification to prevent failures). All encompassing is the notion of autonomous maintenance by operators. TPM seeks to eliminate the 'six big losses': equipment failure, set-up and adjustment, idling and minor stoppages, reduced speed, process defects and reduced yield. Minor stoppages are reduced by lubrication, cleaning, performing adjustments and conducting inspections which are done by operators with maintenance staff performing "periodic inspections and preventive repairs" [63, p. 33].

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