Measuring the alignment of Maintenance and Manufacturing Strategies – The development of a new model and diagnostic tool

Dr Kenneth Robson (Corresponding author)
Faculty of Applied Sciences, University of Sunderland
St Peters Campus, David Goldman Building, Sunderland, SR6 0DD, United Kingdom
Tel: +44(0) 515 2881 E-mail: ken.robson@sunderland.ac.uk

Professor John MacIntyre
Faculty of Applied Sciences, University of Sunderland
St Peters Campus, David Goldman Building, Sunderland, SR6 0DD, United Kingdom
Tel: +44(0) 515 3859 E-mail: john.macintyre@sunderland.co.uk

Dr Robert Trimble
Faculty of Applied Sciences, University of Sunderland
St Peters Campus, David Goldman Building, Sunderland, SR6 0DD, United Kingdom
Tel: +44(0) 515 3859 E-mail: rob.trimble@sunderland.co.uk

Abstract

Purpose - To outline the development of a new conceptual model and diagnostic tool which assesses the strategic processes and links involved between maintenance and manufacturing strategies and the effect on manufacturing performance.

Methodology - The new model was developed in two stages. Firstly a conceptual framework was produced and then a holistic diagram. From this theoretical model a diagnostic tool was generated. This tool was then verified and tested during an empirical research phase which produced four extensive and detailed case studies. A brief overview of one of the case studies is provided in this article.

Findings - It was found that the conceptual model provided an accurate representation of the strategic processes and links which should exist in a manufacturing plant. Moreover the diagnostic tool proved to be a valid and reliable test instrument to measure and display this information.

Practical implications - The diagnostic tool provides a snapshot of the status of manufacturing and maintenance strategies which then can be used to benchmark improvements over time. If required the individual questions from the questionnaire can be "reverse engineered" to provide detailed information for senior managers to carry out corrective action.

Originality/value – This theoretical and empirical research closes a gap in the literature relating to the linkage between maintenance and manufacturing strategies. It does so by providing a unique and holistic model showing the strategic processes and links which should exist within a manufacturing plant. Moreover the diagnostic tool produced from the model is a convenient audit facility which enables companies to move toward functional coherence.

Keywords: linkage, maintenance strategy, manufacturing strategy, conceptual framework, contextual factors

1 Introduction

Manufacturing is important to the UK economy because it contributes 10% to GVA, employs 2.5 million people and produces half of UK exports (EEF, 2012). To be successful in the global economy, UK manufacturing companies have to continue to produce goods and services that customers need, at the right price, so they can compete and survive. The development of operational strategies can serve to improve and tailor the product offering for customers as well as improve the internal efficiency and effectiveness of manufacturing plants. Operational or plant strategies are made up of a mixture of functional strategies of which two key functions are maintenance and manufacturing. For maintenance and manufacturing strategies to be successful, they need to be linked to corporate, business and marketing objectives (Skinner, 1969, Hill, 1985, Pinjala et al., 2004). However in practice few manufacturing companies create maintenance strategies and link them to their manufacturing and business goals (Jonsson, 1997). Furthermore, there is little in the published literature to suggest that there is any common agreement on the process for the formulation and execution of functional strategy. Moreover, there is no comprehensive diagram or model which portrays how these functional strategy processes should be connected together and linked externally. Without knowing the specific components and how they fit together it is challenging for practitioners and researchers to assess the status of operational strategies and solve any problems if and when they arise.

This paper presents a new model and diagnostic tool which offers a potential solution to this problem. The new model includes a diagrammatic representation of how maintenance and manufacturing strategies should be connected together and how they should link to the external environment. It will be shown how this framework was further evolved into a new diagnostic tool. The new tool makes it easy for practitioners to identify areas for improvement and through a process of reverse engineering questions from the questionnaire can help rectify issues by pointing to the necessary corrective action.

The paper is structured as follows: First, the background to the study is given followed by an explanation of the development of a new conceptual model and diagnostic tool. Then the research methodology is outlined describing the methods and approaches underpinning the research design. Leading on from this a précis of one of the case studies is provided to demonstrate the output from the diagnostic tool. Finally, the paper is concluded with a summary of the contribution, methodology, limitations and recommendations for further research.

2 Background

The body of knowledge concerning manufacturing and maintenance strategies is largely based on strategic management and much of the theory has been adopted or adapted from corporate strategy literature. Being successful in business is about delivering the right mix of products and services to enable a firm to profitably compete in a marketplace. The continual search to find ways of achieving this goal has proved a challenge for academics and management practitioners alike. This is evidenced by the plethora of writings on strategic management and a proliferation of models, theories and frameworks concerning corporate strategy (Ackoff, 1981, Porter, 1985, Certo, 1991, Mintzberg and Quinn, 1991, Mintzberg et al., 1998). As a result, a number of *strategy schools* emerged (Mintzberg et al., 1998) and these embraced a spectrum of opinion ranging from determinism to voluntarism (Genus, 2000). Despite this wide range of views the dominant epistemology amongst corporate strategy literature is the *rational planning paradigm* (Ackoff, 1981, Ansoff, 1988, Johnson and Scholes, 1993). Here, strategy (or how to compete) is formulated at a corporate level and cascaded through the organisation in the form of plans, goals and objectives (Certo, 1991, Johnson and Scholes, 1993, Ackoff, 1981). This *top down* approach has pervaded into manufacturing and maintenance strategy literature and is exemplified in the models presented by Skinner (1969) Kim and Arnold (1996), Kelly (1997), Geraerds (1990). Another area of significant interest to this paper lies in the concept that strategy should incorporate *process* and *content* (Voss, 1992). The term *process* relates to the steps or sequences that need to be followed when formulating and implementing strategy whereas *content* concerns what the strategy contains i.e. the strategic choices that are made (Voss, 1995). More specifically the *content* element defines how tangible and intangible resources will be nurtured and deployed in order to create competitive advantage (Skinner, 1969, Hayes and Wheelwright, 1984, Hill, 2000). If the *process* of manufacturing strategy is considered further, there are many frameworks and models to choose from. The seminal work of Skinner (1969) was significant because the majority of manufacturing related research *'has either focused on, or developed aspects from Skinner's work'* Voss (1992). Skinner (1969) was first to draw attention to the need to link manufacturing strategy to corporate strategy and others have suggested that corporate and business strategy be linked to Marketing (Hill, 2000 p 31) and Maintenance (Pinjala et al., 2004). Skinner (1969) also raised the issue that manufacturing could be a *competitive weapon* or alternatively a *corporate millstone* and this was developed further with the advent of the Hayes and Wheelwright (1984 p.396) four stage model which described how the maturity of manufacturing organisations might influence competitive advantage.

Reflecting on the literature in relation to manufacturing and maintenance strategies the authors conclude that the majority of models and frameworks are focussed on a single functional process and interactions with other functions are largely ignored. Although the need to link functional strategies has been discussed by leading authors, few if any have elaborated further or crafted their thoughts into a diagram. Notably, Hayes and Wheelwright (1984 p.30) commented that the horizontal and vertical linkages between functions and business level were often overlooked. Agreeably Hill (2000 p.21) noted the need for congruency between functional strategies and other parts of the business but disparagingly added that *'coherent alignment was unlikely if functional strategies were independently formulated'* (Hill, 2000 p.22). From a maintenance perspective Kelly

(1997 pp. 60-65) acknowledged that the maintenance-production interface was a potential area for conflict and raised the possibility of *horizontal* and *vertical* polarisation between functions due to the *'lack of definition of overlapping responsibility areas'*. In Anthony Kelly's view, this could lead to a *'conflict of attitudes and communications'* and warned against a build-up of antipathy between functional levels feeding and *us* and *them* culture. Having extensively reviewed the body of knowledge in relation to maintenance and manufacturing strategies (Robson, 2010)the only instance where linkage between functional strategies was pinpointed in a diagram was in a conference paper presented by Ward et al. (1990). Like similar models, it described a process from corporate strategy through to market performance and included aspects of formulation and implementation. The overall framework in itself was not new but the way it modelled the relationship between the internal functions was highly innovative. Ward et al. (1990) had in effect, taken the conceptual need for linkage expressed by others i.e. Hayes and Wheelwright (1984), and Hill (1985), and showed functional processes linked together in a parallel fashion. Accordingly a new model was developed which consolidated the configuration postulated by Ward et al. (1990) with a generic functional strategy process adapted from the models offered by Kim and Arnold (1996) and Kaplan and Norton (2001). The new model presented in this paper is meritorious because it is usable, concise yet holistic. It provides sufficient information to discern the fundamental functional process steps but not too much information which would make the model convoluted and over complex. Section 3.1 details the development of the new model.

3 Conceptual model and diagnostic tool

3.1 Model development

The new model was developed using a methodology proposed by Miles and Huberman (1994). This inductive approach involved two basic steps. Firstly, a conceptual framework was generated based on the experience and expert knowledge of the authors, then a model was developed and justified by underpinning the conceptual framework with theory. The process is described in more detail next.

Step 1 – The Conceptual Framework

According to Covey (1999) everything is created twice, first of all in the mind and then in the real world. This is an accurate expression of how the conceptual framework was developed. The thought process involved absorbing, reflecting and synthesising practical and theoretical knowledge then using this information to visualise an *ideal scenario* for a strategic process within a plant. To define this, an observer was imagined to be looking outward from the manufacturing plant watching business objectives arrive at a *strategic* level. The objectives would then be processed by senior managers and converted into functional strategies and action plans. The action plans would then be cascaded down to the *operations* level and implemented by supervisors, operators and craftsmen. By use of control systems e.g. PDCA cycle (Slack et al., 2007) all plans and targets would be met. Since both functional strategies were perfectly aligned and coherent, the functional outputs from manufacturing and maintenance would combine together in a positive manner to improve the overall plant performance. The results of the *ideal* scenario would be output at the *performance* level delivering the improvements required by external stakeholders and the company. This scenario or conceptual framework was used as the basis of the model.

Step 2 – The building and underpinning of the model with theory

The wording of the conceptual framework was scrutinised and three model constructs emerged. Firstly, a *boundary* was identified between the manufacturing plant and the outside world. Secondly, the functional strategies were noted to be *top down* with three distinct levels i.e. strategy, operations and performance. Finally, the two strategies manufacturing and maintenance needed to be coherently connected together. The next step in the development process was to align these three constructs with existing theory and use this conventional wisdom to build the new conceptual model.

Construct 1 - Internal and external environments

The first element to consider was the *boundary* between the plant and the outside world. This concept aligned well with the notion of *interna*l and *external* environments often referred to in Business and Strategic Management literature e.g. environmental analysis (Oliver, 1990), PEST analysis (Johnson and Scholes, 1993), competitive analysis (Porter, 1985). The first part of the model was therefore readily achieved by splitting the diagram into two halves, one half representing the internal environment of the plant and the other half representing the external environment i.e. corporate level, competitors, suppliers etc. This arrangement is shown as *construct 1* in Figure 1. It will be noticed that the orientation of the diagram is horizontal which aligns with the conceptual framework description i.e. the observer imagined to be standing on the left hand side of the page looking outward from the plant towards the external environment.

Construct 2 – A functional process with three levels

To build and justify the functional process two further models were identified from the literature. Firstly, the Kim and Arnold model (1996) provided the basis for the three stage process which was further enhanced with bi-directional feedback based on the Kaplan and Norton model (2001). The resulting functional process is depicted as *construct 2* in Figure 1 and is treated as a generic process for either discipline.

Construct 3 – Connecting together the Functional strategies

The final part of the new model which needed clarification was the interconnection between the two functional strategies. Accordingly the parallel connection proffered by Ward et al (1990) was incorporated into the design which produced the matrix shown as *construct 3* in Figure 1. Bringing together the three constructs the new model is shown in Figure 2.

3.2 Interpretation of the model

To interpret the model the description outlined in Step 1 should be followed. The model defined in Figure 2 shows three stages or levels; *strategy*, *operations* and *performance*. Essentially, objectives are set by external stakeholder's i.e. corporate level, customers or marketing and these arrive into the plant at the *strategy* level. At this point senior managers develop functional strategies and action plans and devolve these vertically to the *operations* level for implementation. Here it is expected that plans are controlled and measured using feedback on progress to ensure the agreed targets are met. If all the processes and links described by the model are in place, it is assumed that plant objectives will be achieved and a set of improved products and services will be output at the performance level. In practice research has shown that functional strategies within manufacturing plants are often impaired by contextual factors (Pettigrew, 1987) and this can impact their successful formulation and execution (Barnes, 2002). It therefore follows that the *ideal* scenario described above may not play out perfectly in practice because often these processes or links are absent or inhibited. This observation is fundamental to the development of the diagnostic tool described next because comparison between the actual status of the plant and the *ideal* scenario yields the points of failure or high resistance which need to be corrected. By identifying and rectifying these deficiencies in the strategic framework, it is more likely that functional, plant and business strategies will succeed.

3.3 Development of the diagnostic tool

The new model provided a framework which identified the key processes and links involved in the formulation and execution of maintenance and manufacturing strategies. The following discussion describes how this framework was used as the basis of a new diagnostic tool.

The basic shape of the diagnostic tool was based on the structure of the model shown in Figure 2 and the development began by replacing the bi-directional arrows with boxes. This generated a 13-way matrix which is shown in Figure 3. The next important step was to define the purpose of each box with a *key question*. Firstly, to clarify the *vertical* components of each functional strategy i.e. Boxes 1, 5, 8, 10, 13 and 3, 4, 6, 9, 11 a more detailed functional process was developed as shown in Figure 4. This used a combination of the *hard systems model* (Bignell et al., 1984) and the *plan, do, review* process given in Slack et al. (2007). Secondly, the horizontal components were determined. In this case, Boxes 2,7,12 were less well researched so an assessment was made based on expert knowledge and experience. This generated a complete set of key questions as outlined Figure 5. Once the key questions were established a number of supporting supplementary questions were developed from the literature and this used to form a comprehensive questionnaire. This consisted of 13 sections which aligned with the boxes in the tool. However when the questionnaire was completed the number of questions in each section differed. To ensure consistency of display across the tool, a proportional scale was developed for each combination of questions. For example, if the data for the Foodco[1] plant Box 1 in Table 1 is considered, it will be found that the number of supplementary questions in this section were twelve. This gave a possible range of scores between 12 and 60 (because the minimum and maximum score on the Likert scale was one and five respectively). The scale was produced by dividing the total range of 48 into three sections each approximating to a third of the range for each colour; red, amber or green. Scores in the *red* section indicating: little if any of the criteria met, *amber*: most of the criteria met and *green*: all or the majority of criteria met. Therefore, for the example shown in Table 1 the score for Box 1 was 27 so this fell in the *red* region. By repeating this process, colours representing the status for each box were derived resulting in an overall *footprint* as shown in Figure 6. The finalised diagnostic tool can be described as having two key components, a

[1] The label Foodco has been used to secure the anonymity of the company.

questionnaire which acts as a *probe* to measure the condition of each process and link and an output *display* which visually enunciates the overall status of the manufacturing plant.

4 Methodology

The research began with an extensive literature review revealing a gap in the body of knowledge in relation to maintenance and manufacturing strategies. Because there was no suitable model or framework available a new model was developed (Robson, 2010). From this, a diagnostic tool was generated. The questionnaire utilised a five point Likert scale similar to that used by Barnes (2002) and is of a type widely used in social research to measure opinion/attitude (de Vaus, 2001). Each question had the same set of options; strongly agree = 5, agree = 4, neither agree nor disagree = 3, disagree = 2, strongly disagree = 1. Once the questionnaire was developed the questions and format were further scrutinised by an expert panel and then piloted at a manufacturing site. From the feedback obtained minor changes were made to the questionnaire to make it more usable in the field.

At the commencement of the empirical research phase, four companies were selected based on their suitability, interest and willingness to engage in the research. The companies chosen were from the Automotive, Pharmaceutical, Food and Steel making industries which meant that any data, although not necessarily generalisable (Yin, 2003) would not be biased by any specific industrial sector. The main approach to data collection was via semi-structured interviews which were recorded, transcribed, coded and analysed. The assessment of questions was based on a mix of sources: Observation, Interviews and Company information and identified in the supporting evidence behind each case study and notated as (O), (I) or (C). Figure 7 gives a sample of the extensive textual evidence which was used to support and justify the responses to each question in the questionnaire of each case study. In the case of data from interviews, the textual information was coded and anonymised by job name, recording filename and the position in file where the quotation was taken from. This meant that all data was traceable back to the original digital recording. The resulting scores from the questionnaire were then processed as described previously to colour and show the status of each box in the diagnostic tool. From this information a *footprint* and a descriptive case study was formed to feedback the results to each site.

Whenever research is carried out there is need to collect and analyse data but when doing so care must be taken with the research design to ensure that the findings are reliable and valid. It is also important that the results of the research are repeatable (Bryman.A, 2001 p.29). In this research, many tactics were deployed to guard against these issues. In terms of *construct* validity it was important to make sure that the *instrument* that was developed "measured what it was supposed to measure" (Robson, 2005 p.102), so for example extra care was taken over the wording of questions in the questionnaire to ensure respondents understood the question consistently (de Vaus, 2001 p.31). Furthermore a cross section of opinion from different respondents enabled the reduction in constant and random errors (de Vaus, 2001 p.31). A *multiple respondent* approach was also adopted which involved questioning a cross section of the organisation i.e. managers, supervisors and shop floor staff. By aligning questions to appropriate staff and checking responses between interviews it was ensured that all questions were answered by knowledgeable staff and the possibility of the bias of results due to *self-reporting* minimised (Voss et al., 2002 p.205). Moreover the deployment of a case study approach ensured multiple sources of evidence i.e. interview, company documents, observation helping remove bias.(Yin, 2003 p.97). Overall, this established a chain of evidence which clearly linked the research question, data and results (Yin, 2003 p.106). Finally, key informants reviewed drafts of their case studies and verified that the results and recommendations generated by the diagnostic tool and questionnaire were valid and accurate (Yin, 2003 p.34). To address *internal* validity i.e. would the research design sustain the causal conclusions that it claimed (de Vaus, 2001 p.27) other safeguards were deployed in this study. Firstly, as advised by Yin (2003 p.112) rival explanations were curtailed by comparing characteristic and exemplars against known strategic patterns. Secondly, *explanation building* was provided in a narrative form via the cross-case analysis (Yin, 2003 p 121). Finally logic modelling was used to assess empirically observed events against theoretically predicted events (Yin, 2003 p 127). Furthermore, e*xternal* validity was improved in two ways, by employing multiple case studies (Voss et al., 2002 p 211) and by making analytical rather than statistical generalisations (Robson, 2005 p. 183). In terms of *reliability* (de Vaus, 2001 p 30) and *repeatability* (Bryman.A, 2001 p 29) of results this was promoted first of all by use of a case study protocol which was established and followed (Yin, 2003 p 67-68). Secondly, the design and reliability of the questionnaire was improved through the use of a Likert scale which is a Multiple-item indicator. Finally but not exhaustively, questions were carefully worded and verified by a panel of experts which helped improve *face validity* i.e. on the face of it the experts believed the questions would measure what they were intended to measure.

5 Case study example

The authors have included here a synopsis of the outputs and data generated from one of the four manufacturing plants studied. It is not intended as a full presentation of the results from the empirical research. This will be the subject of another paper.

Foodco is a food manufacturing plant based in the North East of England. Its manufacturing hall consists of three production lines which are made up of basic equipment which provide mixing, conveying, heating and packaging functions. The production lines are afforded with extra capacity which allows for additional volume to be produced should another sister plant have a breakdown. At the time of the case study the processes were arranged in a *product* or *flow line* configuration (Slack et al., 2007) and *made to order* batch processing was deployed to meet the stringent *Just in time* schedules. The maintenance department responsible for the equipment were centrally organised and consisted of twelve craftsmen working a four-shift rota. There were three craftsmen on dayshift and the whole group was supported by a Planner and two Engineers. The main approach to equipment maintenance was planned preventative.

Following a series of interviews with staff, the rich data were analysed and used to complete a questionnaire. The scores were determined and the relevant colour identified using the ranges shown in Table 1. This information was then used to produce the diagnostic *footprint* for Foodco shown in Figure 6. Once the diagnostic footprint was produced, a synopsis of the status of the strategic processes could be carried out.

If the Foodco footprint in Figure 6 is considered further, it is evident that the Plant was not meeting its overall performance targets because Box 13 was red. Closer inspection of the footprint suggests there were issues with the formulation and execution of manufacturing strategy and the formulation of action plans. This was indicated by Box 1 = red and Box 5 = amber. Although adequate systems appeared to be in place to control and measure performance i.e. Box 10 = amber, manufacturing targets were not being met. The status of the maintenance function was of more concern because there was no evidence of any attempt to form strategy or plans i.e. Boxes 3 and 4 were red. In addition, the Maintenance group were failing to meet the required performance levels indicated by Box 11 being red. Furthermore, it was noted that there were few signs of any cohesive linkage between the two functions as Boxes 2, 10, 7 were also red. Overall, Maintenance were not meeting their targets or positively contributing to manufacturing at any level: strategic, operational or performance.

The authors believe that the commentary above demonstrated that the diagnostic footprint can draw out a significant amount of useful information and at the same time highlight the main problem areas affecting strategic flow in the manufacturing plant. However to correct the underlying problems more information was needed. This was provided by further interrogating the responses in the questionnaire and by identifying the questions which were marked low and contributed to poor overall scores. For example, Figure 8 shows a section of the completed Foodco questionnaire. In this case, the overall score was 27 and Box 1 was red. Contributing to this low score were several responses which were rated *strongly disagree*, *disagree* or *not sure*. So these questions were reverse engineered to form the keys areas for corrective action e.g. from Q1.3 develop a set of manufacturing objectives which are **S**pecific, **M**easurable, **A**chievable**, R**ealistic**, T**imely i.e. 'SMART'.

6 Conclusions

6.1 Research Contribution

The authors have described a new model and diagnostic tool which measures the processes and links in relation to maintenance and manufacturing strategy. In addition, the model provides a practical and useful tool for practitioners and managers to use in the field. The new conceptual model has added to the body of knowledge by integrating several strands of theory into a single and concise holistic diagram. In so doing, the model clarifies the horizontal and vertical relationships which should exist between Maintenance and Manufacturing strategies. The authors believe that the diagnostic tool represents a practical contribution which is capable of assessing and diagnosing the status of manufacturing and maintenance strategies within a manufacturing plant. The tool, and the process of using the tool, generates detailed information that senior managers can use to assess, and analyse performance, as well as identify areas for improvement.

6.2 Methodology

The diagnostic tool was tested and evaluated by *dry running* the full data collection and feedback process at four manufacturing sites. This allowed the functionality, reliability and accuracy of the model, questionnaire and tool to be tried and verified in the field from an operational perspective. Feedback from managers reaffirmed that the diagnostic tool produced a realistic snapshot of the status in the plants at the time and that it had highlighted many of the key issues that needed to be worked on. Reflecting on the methodology as a whole, the case study and semi structured interviews proved successful in extracting the necessary information to test and evaluate the model and diagnostic tool. The resulting footprints showed the status in the plants and were useful, relevant and fit for purpose. In practice the diagnostic tool and questionnaire, do not need a consultant to carry out the audit. The manufacturing staff themselves can achieve this. A cross functional team would be a suitable approach to adopt but to ensure the necessary data was gathered, the appointed staff would need to be given management support and the necessary authority and autonomy to carry out the audit independently. Management Implications

Senior managers need to be more aware of the status of their strategic processes at an operational level otherwise their well-constructed business strategies may not be fulfilled in practice. It is not sufficient to delegate the responsibility of forming and implementing functional strategies to operational staff without some level of monitoring which ensures that the necessary processes and actions are in place. The provision of a tool in itself will not overcome this issue or suddenly cause companies to create maintenance strategies and link them to their manufacturing and business goals. This auditing regime has to be initiated and managed by senior staff and this is when the diagnostic tool will become most useful and effective.

6.3 Limitations of the study

The function and efficacy of the model and diagnostic were tested and validated during the case studies and the tool was shown to be capable of accurately measuring the status of the strategic processes and links at each site. However, the ability of the tool to measure the alignment between maintenance and manufacturing strategies, whilst part of the work undertaken by the authors, is not covered in this paper. Furthermore the diagnostic tool was not yet been verified over an extended period of time. Ideally, this would involve taking *snapshots* of the status of a plant at timely intervals but this would require further longitudinal or action research which was outside the scope of this study.

6.4 Further Research

Further longitudinal or action research is needed to test whether the tool to deliver improvements in manufacturing performance over an extended period of time. The authors believe that such further work wold demonstrate that when the directed corrective action recommended by the tool is instigated, significant improvements are achieved over time. Another possible use of the model is to adapt it to describe the linkage between other functions e.g. Finance/Manufacturing, Human Resources/Manufacturing or other combinations, and assess these effects.

7 Acknowledgements

We would like to thank the Regional Development Agency 'One North East' for sponsoring this research as part of the Engineering Fellows Programme. We are also indebted to the companies who participated in this research who allowed us access to their premises and staff providing valuable feedback and information.

8 References

ACKOFF, R. 1981. *Creating the corporate future*, John Wiley & Sons,Inc.

ANSOFF, I. 1988. *Corporate strategy*, Penguin.

BARNES, D. 2002. The complexities of the manufacturing strategy formation process in practice. *International Journal of Operations*, 22**,** 1090-1111.

BIGNELL, V., CARTER, R., MARTIN, J., NAUGHTON, J., PETERS, G., SPEAR, R. & TAIT, J. 1984. *The hard systems approach - systems models*, The Open University Press.

BRYMAN.A 2001. *Social research methods*, New York, Oxford University Press.

CERTO, S. 1991. *Strategic management*, McGraw-Hill Inc.

COVEY, S. R. 1999. *The 7 habits of highly effective people : restoring the character ethic.*, London, Simon & Schuster.

DE VAUS, D. 2001. *Research design in social research*, London, Sage Publications.

EEF. 2012. *Manufacturing – the foundations of a new economy* [Online]. Available: http://www.eef.org.uk/NR/rdonlyres/1EC00841-E738-44A3-A837-DFBEC00DF99B/20520/EEF_FactCard_2012.pdf.

GENUS, A. 2000. *The management of change : perspectives and practice*, Thompson Business Press.

GERAERDS, W. M. J. The EUT maintenance model. *In:* MARTIN, H. H., ed. New Developments in Maintenance, 1990 Netherlands. Ernst & Young Consultants.

HAYES, R., H & WHEELWRIGHT, S., C 1984. *Restoring our competitive edge :(Competing through manufacturing)*, John Wiley & Sons.

HILL, T. 1985. *Manufacturing strategy - The strategic manufacturing choice*, The Macmillan Press.

HILL, T. 2000. *Manufacturing strategy : text and cases,* Bristol, J.W.Arrowsmith Ltd.

JOHNSON, G. & SCHOLES, K. 1993. *Exploring corporate strategy*, Prentice Hall.

JONSSON, P. 1997. The status of maintenance management in Swedish manufacturing firms. *Journal of Quality in Maintenance Engineering,* 3**,** 233-258.

KAPLAN, R. S. & NORTON, D. P. 2001. Transforming the Balanced Scorecard from performance measurement to strategic management - Part 2. *Accounting Horizons,* 15**,** 147-160.

KELLY, A. 1997. *Maintenance organization & systems - business-centered approach*, Athenaeum Press Ltd.

KIM, J. & ARNOLD, P. 1996. Operationalizing manufacturing strategy: An exploratory study of constructs and linkage. *International Journal of Operations and Production Management,* 16**,** 45-73.

MILES, M. B. & HUBERMAN, A. M. 1994. *Qualitative data analysis,* London, Sage.

MINTZBERG, H., AHLSTRAND, B. & LAMPEL, J. 1998. *Strategy safari*, The Free Press.

MINTZBERG, H. & QUINN, J. B. 1991. *The strategy process - concepts, context, cases,* Prentice Hall Inc.

OLIVER, G. 1990. *Marketing today*, Prentice Hall International Uk. Ltd.

PETTIGREW, A. M. 1987. Context and action in the transformation of the firm *Journal of Management Studies* 24.

PINJALA, S. K., PINTELON, L. & VEREECKE, A. 2004. An empirical investigation on the relationship between business and maintenance strategies. *International Journal of Production Economics*.

PORTER, M. E. 1985. *Competitive advantage - creating and sustaining superior performance*, Free Press, New York.

ROBSON, C. 2005. *Real world research*, Blackwell Publishing.

ROBSON, K. 2010. *An investigation into the impact on manufacturing performance of the linkage between maintenance and manufacturing strategy.* Unpublished PhD Thesis, University of Sunderland.

SKINNER, W. 1969. Manufacturing - missing link in corporate strategy. *Harvard Business Review***,** 1-10.

SLACK, N., CHAMBERS, S. & JOHNSON, R. 2007. *Operations management*, Prentice Hall.

VOSS, C., A. 1992. *Manufacturing strategy - process and content*, Chapman & Hall.

VOSS, C., A. 1995. Alternative paradigms for manufacturing strategy. *International Journal of Operations & Production Management,* 15**,** 5-16.

VOSS, C., A., TSIKRIKTSIS, N. & FROGLICH, M. 2002. Case research in operations management. *International Journal of Operations & Production Management*, 22**,** 195-219.

WARD, P., LEONG, G. & SNYDER, D. Manufacturing strategy: An overview of current process and content models. *In:* ETTLIE, J., BURSTEIN, M. & FIEGENBAUM, A., eds. Manufacturing strategy : the research agenda for the next decade :, 1990 Norwell Ma. Kluwer Academic Publishers, 189-199.

YIN, R. K. 2003. *Case study research - design and methods*, Sage Publications London.

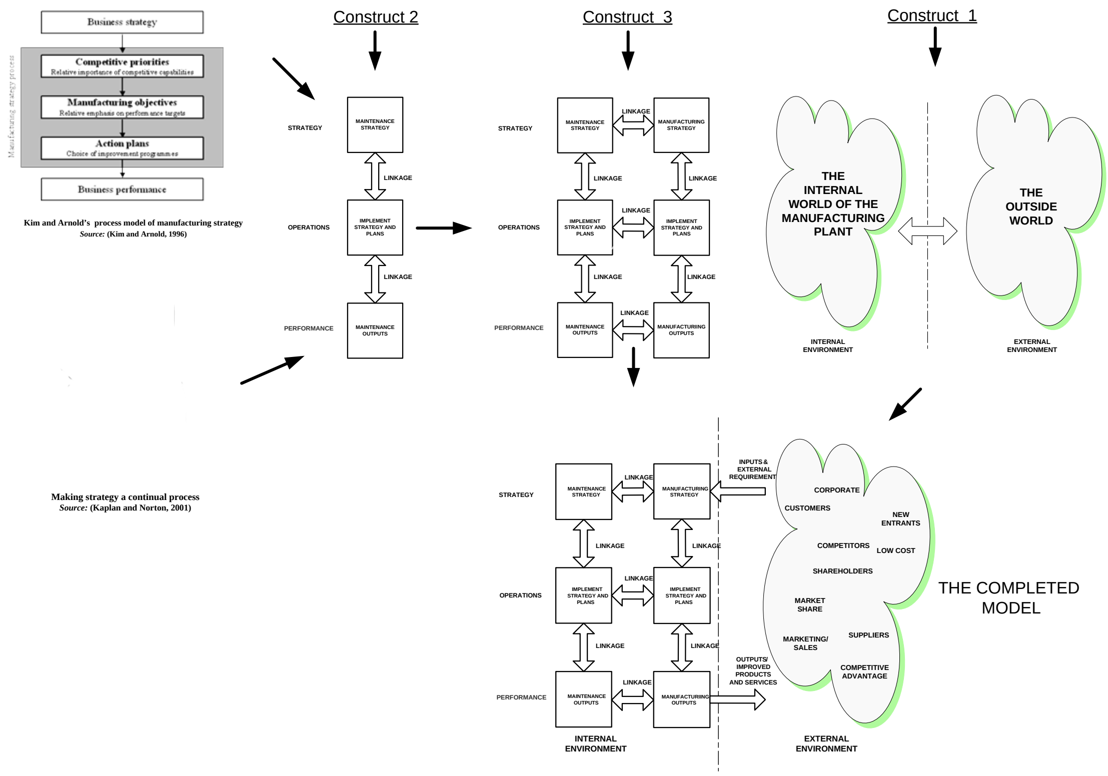

Figure 1. The construction of the new conceptual model

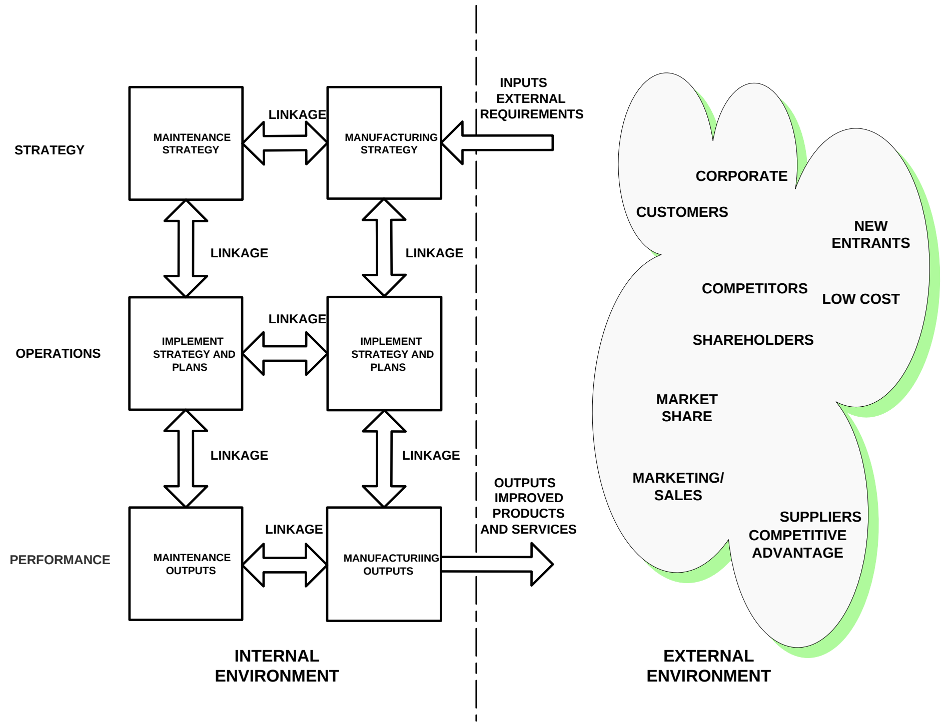

Figure 2. The new conceptual model

`

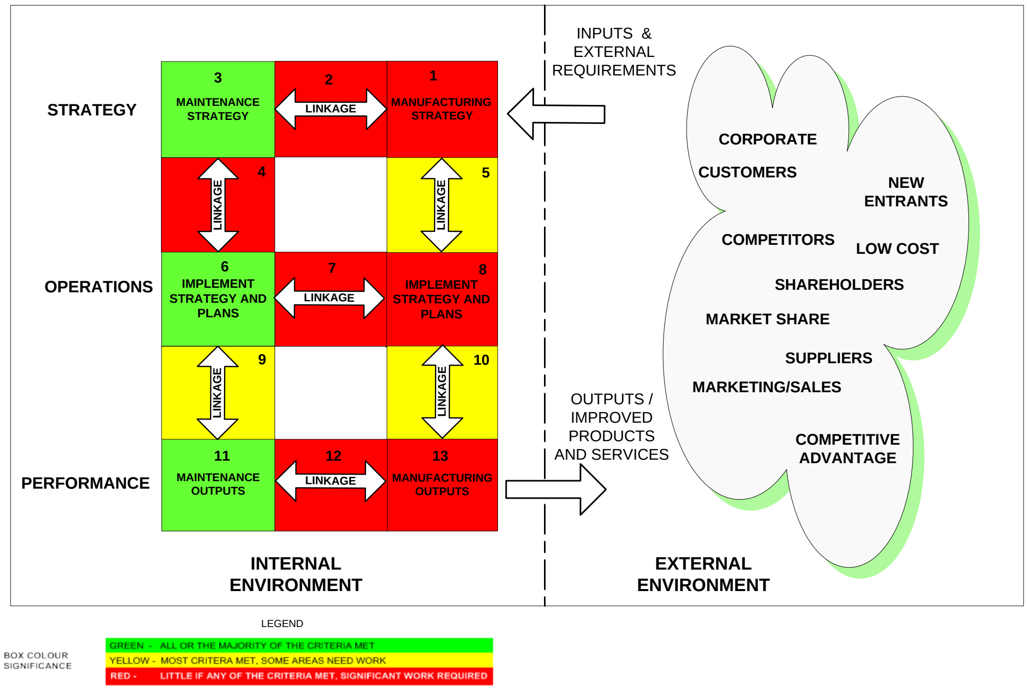

Figure 3. The new diagnostic tool

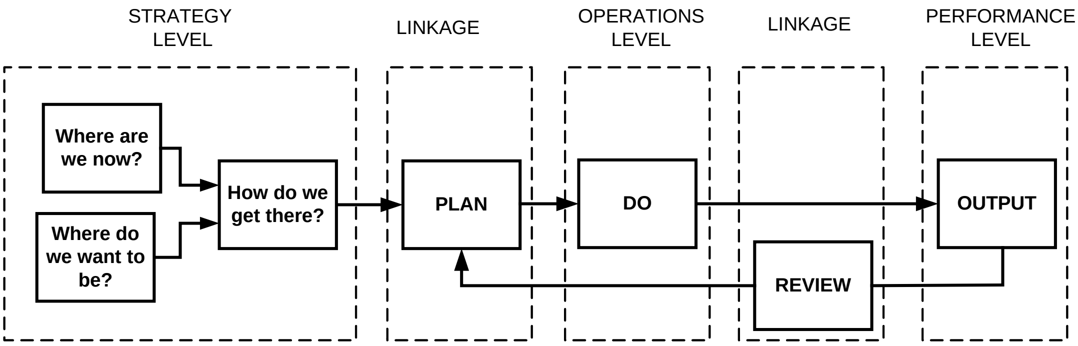

Figure 4. The definition of the levels and linkages of functional strategy
Adapted from **Bignell (1984) and (Slack et al., 2007)**

Is there a maintenance strategy? 3	Has an agreed set of objectives been established between maintenance and manufacturing? 2	Is there a manufacturing strategy? 1
Are there a set of documented plans to implement the maintenance strategy? 4		Are there a set of documented plans to implement the manufacturing strategy? 5
Are the maintenance action plans being implemented in the workplace? 6	Do maintenance and manufacturing groups work together to meet mutually agreed objectives? 7	Are the manufacturing action plans being implemented in the workplace? 8
Is the progress against action plans controlled, measured and reviewed? 9		Is the progress against action plans controlled, measured and reviewed? 10
Are maintenance meeting or exceeding their performance targets? 11	Has maintenance strategy had a positive effect on manufacturing performance? 12	Are manufacturing meeting or exceeding their performance targets? 13

Figure 5. **The "key questions" for the diagnostic tool**

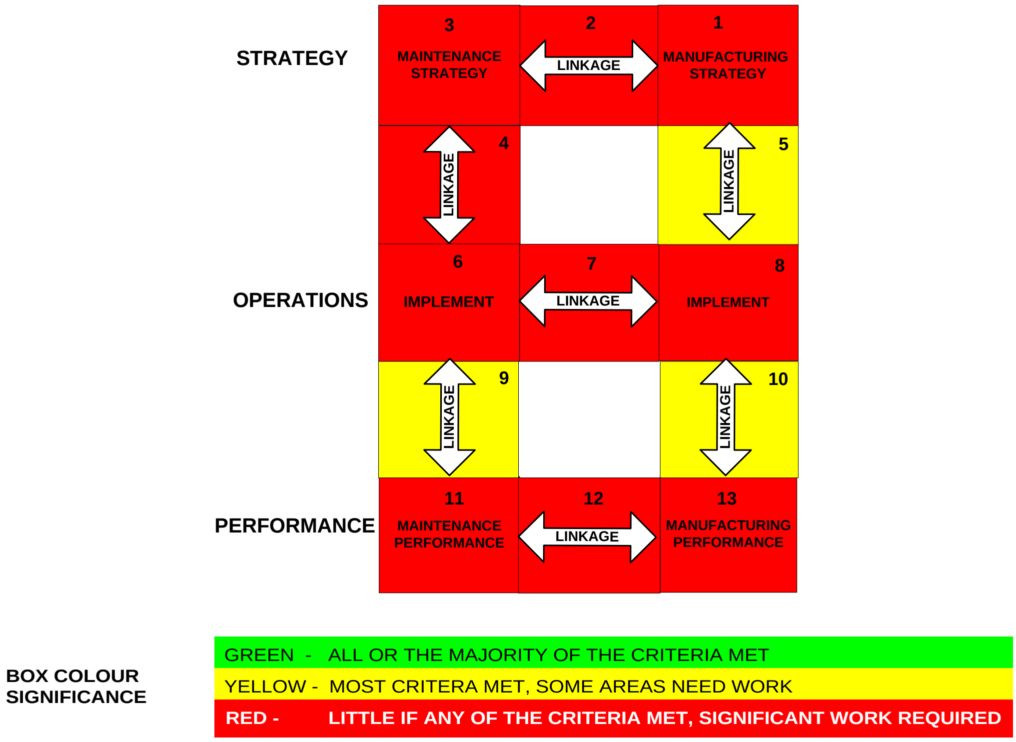

Figure 6. The example diagnostic footprint for Foodco

FOODCO								
Box No.	No. of Questions	Max. score	Min. score	Range			Actual score	Outcome
1	12	60	12	12 - 27	28 - 44	45 - 60	27	Box 1 is red
2	5	25	5	5 - 11	12 - 18	19 - 25	5	Box 2 is red
3	9	45	9	9 - 20	21 - 33	34 - 45	14	Box 3 is red
4	5	25	5	5 - 11	12 - 18	19 - 25	7	Box 4 is red
5	5	25	5	5 - 11	12 - 18	19 - 25	15	Box 5 is amber
6	7	35	7	7 - 16	17 - 25	26 - 35	9	Box 6 is red
7	3	15	3	3 - 6	7 - 11	12 - 15	3	Box 7 is red
8	5	25	5	5 - 11	12 - 18	19 - 25	5	Box 8 is red
9	5	25	5	5 - 11	12 - 18	19 - 25	17	Box 9 is amber
10	5	25	5	5 - 11	12 - 18	19 - 25	17	Box 10 is amber
11	4	20	4	4 - 8	9 - 15	16 - 20	4	Box 11 is red
12	3	15	3	3 - 6	7 - 11	12 - 15	3	Box 12 is red
13	4	20	4	4 - 8	9 - 15	16 - 20	4	Box 13 is red

Table 1. Scoring information and outputs from Foodco questionnaire

Q1.1 KEY QUESTION FOR BOX 1: IS THERE A MANUFACTURING STRATEGY?

Q1.2 There are a set of manufacturing objectives developed from the business objectives (I) (C)

There were business objectives as evidenced by Appendix 7 and 8.

"Within the business we have the corporate business strategy and the UK business strategy and within that, there's seven defined success factors: profitability, quality, safety,,, all the way through. They are then split off into what are the business key KPI's. We then as a region take the seven critical success factors and we define our own five year strategy (Appendix 7), then we have our tactical plan (Appendix 8) which is our current operating plan, what we gonna do this year, which drives down into the departments: Engineering, Manufacturing, Quality, HR and that's where the functional heads are".
[Plant manager refer DM10179, pos. 2.24]

Objectives were more a series of initiatives and projects rather than targeted improvements.

"Throughout all of this(the strategy) is the culture required in the organisation. How you deliver all of this, that's very key to us, what we deliver and how we deliver. Certain projects support all of this, the growth of the business, EAM, Diamond, Pulse, capital investment, to me they are all underpinning the delivery of the strategy. So for example EAM is not an Engineering project it is a cultural change project, it's the way we do things".
[Plant manager refer DM10179, pos. 02.24]

The main delivery of the plan was based on the culture and involving the people. There were a set of manufacturing objectives conveyed to the Production Supervisors.

"What we have obviously John, being the Operations Manager gets the top level objectives coming through to himself, normally then what would happen is he would sit down with each of us on an individual basis with myself and the other three FLM's , we'll go through what the business is looking at over the next six to twelve months , You'll not necessarily have a plan as such but there'll be basic objectives that we'll be set that we'll have to meet".
[Front Line Manager 1 refer DM10142, pos. 18.04]

Table 2 Sample of evidential data used to justify responses to questions

Manufacturing		
1.1	IS THERE A MANUFACTURING STRATEGY?	YES If 'NO' go to 2.1
1.2	There are a set of manufacturing objectives developed from the business objectives	Not sure = 3
1.3	The manufacturing objectives are 'SMART' i.e. Specific, Measurable, Achievable, Realistic, Timely	Disagree = 2
1.4	The current state of these objectives has been established i.e. the status of the areas relating to the manufacturing objectives have been measured and assessed	Disagree = 2
1.5	The manufacturing process is defined and mapped	Agree = 4
1.6	The manufacturing process has been divided into manageable sections	Agree = 4
1.7	Each process section is measured for yield, throughput and availability	Strongly Agree = 5
1.8	A manufacturing strategy has been formed by comparing the 'current state' to the 'future state' and assessing how the gap can be bridged.	Strongly Disagree = 1
1.9	The manufacturing strategy specifies what needs to be done to meet the manufacturing objectives.	Strongly Disagree = 1
1.10	The manufacturing strategy is documented	Strongly Disagree = 1
1.11	Key Performance Indicators (KPI's) have been developed for each manufacturing objective	Disagree = 2
1.12	All 'key stakeholders' have been involved with the development of the 'manufacturing strategy'	Strongly Disagree = 1
1.13	The Manufacturing Strategy has been clearly communicated to the whole organisation, both verbally and visually	Strongly Disagree = 1
	TOTAL SCORE FOR BOX 1	27
	RANGE: 12 - 27 28 - 44 45 -60	

Table 3. **Sample section from Foodco questionnaire showing questions for box 1**