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Journal of Materials Processing Technology 139 (2003) 120–126

Journal of Materials Processing Technology

www.elsevier.com/locate/jmatprotec

Systematic innovation and the underlying principles behind TRIZ and TOC

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Abstract

Innovative developments in the design of product and manufacturing systems are often marked by simplicity, at least in retrospect, that has previously been shrouded by restrictive mental models or limited knowledge transfer. These innovative developments are often associated with the breaking of long established trade-off compromises, as in the paradigm shift associated with JIT & TQM, or the resolution of design contradictions, as in the case of the dual cyclone vacuum cleaner. The rate of change in technology and the commercial environment suggests the opportunity for innovative developments is accelerating, but what systematic support is there to guide this innovation process. This paper brings together two parallel, but independent theories on inventive problem solving; one in mechanical engineering, namely the Russian Theory of Inventive Problem Solving (TRIZ) and the other originating in manufacturing management as the Theory of Constraints (TOC). The term systematic innovation is used to describe the use of common underlying principles within these two approaches. The paper focuses on the significance of trade-off contradictions to innovation in these two fields and explores their relationship with manufacturing strategy development.

Keywords: Systematic innovation; TRIZ; TOC; Constraints management; Trade-offs; Manufacturing strategy

1. Introduction

The concept of trade-offs, or conflicting performance parameters is a central feature of mechanical design where speed and efficiency, or strength and weight performance conflicts are readily acknowledged. These are typically well documented and the performance trade-offs are balanced in the design process to give the optimum for a particular application. What is less well known is the significance of these contradictions in the innovation process. The practice of using trade-off parameters as a focus for systematic innovation in mechanical design has only recently emerged from Russia under the name of TRIZ (The Theory of Inventive Problem Solving), but it is already attracting significant industrial interest [1].

In the field of manufacturing it is over 30 years since Skinner [2] used the concept of mechanical design trade-offs to help acknowledge and manage conflicting performance parameters associated with manufacturing. This extract from his seminal work illustrates the mechanical analogy.

> For instance, no one today can design a 500 passenger plane that can land on a carrier and also break the sound barrier. Much the same is true of manufacturing. The variables of cost, time, technological constraints, and customer satisfaction place limits on what management can do, force compromises, and demand an explicit recognition of a multitude of trade-offs and choices. [2]

From this and subsequent papers the strategic trade-offs associated with manufacturing investment and decision-making became explicitly recognised. The term 'manufacturing strategy' emerged with a new awareness of performance conflicts and the need to make strategic choices between competitive criteria, such as speed and efficiency, or quality and cost. Since then the debate has moved on and some of the originally cited trade-offs are acknowledged to have been all but eliminated in certain sectors, with the application of developments such as JIT and TQM, now often cited as heralding a new manufacturing paradigm [3]. As a consequence some would argue the trade-off analogy with mechanical design is no longer relevant [4]. Others argue that trade-offs change [5–7], as with mechanical systems, but the perceived role of the trade-off concept is largely limited to one of acknowledging their existence, so that the negative impact can be minimised.

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0924-0136/03/$ – see front matter © 2003 Elsevier Science B.V. All rights reserved.
doi:10.1016/S0924-0136(03)00192-4

This paper aims to shed new light on this debate by exploring the deeper significance of trade-offs in mechanical design before linking the analogy to organisational improvement and innovative developments in manufacturing. The thesis of this paper is that the concept of performance contradictions has much more to offer than that has been widely acknowledged to date, not only in the design of artefacts but also manufacturing strategy. The paper will outline the TRIZ and Theory of Constraints (TOC) perspectives on performance contradictions, demonstrating the common underlying principles, before exploring the broader significance of trade-offs in manufacturing.

2. TRIZ

Work on TRIZ, a Russian acronym for The Theory of Inventive Problem Solving, began in 1946 when Genrich Altshuller, a mechanical engineer, began to study patents in the Russian Navy. Over subsequent years his desire to structure the inventive process resulted in a range of tools and approaches based on empirical analysis. TRIZ has now been the subject of many person years of development and seen the study of over a million successful patents [8]. The approach has been widely taught in Russia, but did not emerge in the West until the late 1980s. The different solution systems have been derived by abstracting inventive principles from the ongoing analysis of patent data. Several of these focus on contradictions or trade-offs in identifying innovative solutions.

The TRIZ methodology claims that, ‘Inventive problems can be codified, classified and solved methodically, just like other engineering problems’ [9].

There are three premises on which the theory may be viewed: (i) the ideal design with no harmful functions is a goal; (ii) an inventive solution involves wholly or partially eliminating a contradiction and (iii) the inventive process can be structured. Each of these premises will be dealt with in turn.

2.1. The ideal design with no harmful functions is a goal

Finding the ideal solution to a needed effect or function with no additional resources or negative secondary effects is referred to in TRIZ circles as Ideality:

$$\text{Ideality} = \frac{\text{All useful effects or functions}}{\text{All harmful effects or functions}}$$

The ideal being, to achieve all useful effects or functions with no harmful effects or, ideally, any use of resource. One can argue there is little new in this, as a similar emphasis on improving functionality is also evident in widely established approaches such as Value Engineering. However, the difference is that this thinking is central to TRIZ and specialist supporting tools have been developed that specifically concentrate on improving the functionality through innovation rather than the traditional cost cutting or sub-optimisation focus.

2.2. An inventive solution involves wholly or partially eliminating a contradiction

Altshuller’s [10] early work on patents resulted in classifying inventive solutions into five levels, ranging from trivial to new scientific breakthroughs. Through this work he defined an inventive problem as one containing at least one contradiction and that an inventive solution wholly or partially eliminated the contradiction. Altshuller claimed his solution systems could assist innovation at levels 2–4.

2.3. The inventive process can be structured

This early work convinced Altshuller that there was potential to structure the inventive process around trade-off contradictions and it led to several developments, only two of which are introduced here. In each case empirical data was used to develop correlation operators using the principle of abstraction. Fig. 1 illustrates this abstraction process, which classifies problems and solutions in seeking correlation that enables a set of generic problem solving operators or principles to be identified. This basic model will be referred to as we look at two solution systems of classical TRIZ base around contradictions.

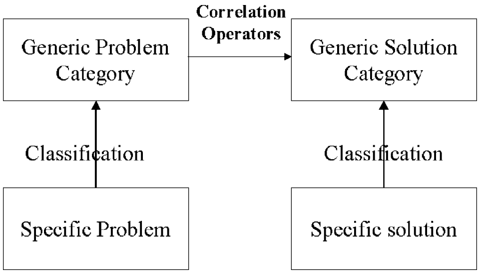

Fig. 1. The general case for abstracting a solution system.

2.3.1. Technical contradiction solution system

After having identified the significance of contradictions Altshuller went on to classify them into 39 parameters and in a similar way he identified 40 common principles that he found had been repeatedly used in patented solutions. To display the possible technical contradiction combinations he produced a 39 × 39 matrix and identified which of the 40 inventive principles were more commonly associated with specific combinations of contradiction parameters. This matrix is called the Technical Contradiction Matrix.

By way of illustration, if one considers Skinner’s aircraft example, a typical trade-off might be speed versus adaptability (e.g. take-off and landing distances). The above TRIZ approach to breaking this contradiction would be to relate the trade-off parameters to the 39 standard technical contradiction parameters to find the closest match. In this case