

## The Relationship between Theory of Constraints and System Dynamics in Operations Management

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### Abstract

The main purpose of this article is to examine the relationship of theory of constraints with system dynamics in operations management. The paper also aims at the presentation of examples showing how deficient managerial decision-making in operations management can be. The theoretical and literature-based article ends with an investigation of the intersection of the theory of constraints and system dynamics. Supporting indications are gathered from different fields of science, for instance, decision science, psychology, sociology, and biology. Examples of apparently deficient decision-making in production contexts are given. It is shown how the theory of constraints and the broader field of system dynamics offers concepts and methods to mitigate some issues of poor decision-making. The complexity of decision making can be eased in the modern business world with the help of the relationship of theory of constraints with system dynamics.

**Keywords:** complexity, decision-making, operations management, system dynamics, theory of constraints.

### Introduction

In the present context of dynamic and complex business world, the ability of management on any hierarchical level to formulate sound policies and to make effective decisions has a substantial influence on success or failure of a firm. The major constraint in most companies is not physical but related to managerial policy and decision-making (Goldratt, 1990). The theory of constraints, conceptualized as a philosophy of continuous improvement, has evolved and expanded its methodological base over time. The theory of constraints methodology comprises three main streams that can be considered as operations strategy tools, performance measurement systems, and thinking process tools (Cox & Spencer, 1998). Gutenberg (1951) identified four factors as the basic input of any production system: materials ('repetitive factor'), machinery ('potential factor'), workforce doing operative work ('human factor'), and directing activity (of course, mainly also done by people but in a different role than in the human factor). The first three are also called elementary input factors; they are combined in order to achieve an efficient way to produce an outcome. The amount to which they are utilised in this combination process is described with the help of production functions. In the production theory literature, different forms of production functions can be found. Elementary factors are supposed to be relatively easy to quantify and calculate (Fandel, 1991).

However, this is not the case for directing activity, which is responsible for the combination process of the elementary factors. In other words, the directing activity symbolises the function of management that plans, organises, controls, and structures the production process.

Gutenberg (1951) and his successors emphasise the importance of the directing activity, most of the time it is only indirectly treated after stating its existence: while efficient combinations of elementary factors are discussed in great depth and length, the directing activity is addressed only insofar as the discussion of factor combinations is meant to support management in fulfilling its task of establishing useful production functions and production environments. In which way the directing activity tries to achieve its goal is not discussed; if and how it can be included into production functions like the rest of the input factors does not find particular treatment in the literature about production and operations management. Even though there is plenty of literature about management in general, there is no production theory that addresses the directing activity in the same way in which the elementary factors are included. Firstly, at the time production theory had its origin, management was a relatively well-structured task—at least compared to the uncertainty and complexity management faces today. Secondly, the directing activity and its influence on production outcome are much more difficult to define and to quantify than the elementary factors. Thus, the reason for the reluctance to include ‘softer’ factors into production theory might also be an educational one: until today the realm of production and operations is dominated by managers with a quantitative, ‘hard-facts’ background, which are presumably not willing to accept qualitative, soft variables in the concepts and methods they use. Thirdly, production theory follows the micro-economic approach of absolute rational decision-making with utility maximising actors (Neumann & Morgenstern, 1944). From this point of view, the directing activity does not really need special attention because its task is completely determined by rationality and therefore rather simple: it just has to employ the most efficient production function which production theory suggests. However, the simplicity vanishes when one considers that knowledge about production functions in real organisations is typically incomplete and fuzzy (Nelson & Winter, 1982). In the contest of Nepal, the literature related to production and operations is very limited. Hence this paper is focused at the presentation of examples showing how deficient managerial decision-making in operations management can be. The paper also explores the relationship of theory of constraints with system dynamics through existing literatures in the scope of the study.

### **Theory of constrains**

Theory of constrains has been developed from dealing with ‘hard’ issue to also addressing ‘soft’ factors (Rahman, 1998). In the beginning, capacity backlogs and machinery or workforce constraints were the major issues of consideration. To a great deal, theory of constrains was understood as an algorithmic method to smooth the technical process of production. This interpretation was partly induced by the success and publicity of methods like ‘optimized production timetables’ (Goldratt, 1980. Goldratt (1988) emphasised on a sheer quantitative and technical approach to also include qualitative aspects of production and general management. An important role in this transition from algorithmic method to managerial concept plays the so-called ‘thinking process’, which is nowadays accepted as the probably most influential part of the whole ‘theory of constraints’ (Noreen et al., 1995).

Without describing the ‘thinking process’ in further detail at this point, already the wording makes clear that cognitive characteristics of decision subjects become crucial in production. Decision subjects constitute the directing activity in Gutenberg’s terms. It is the management as an individual or a group that decides on how production is conducted and which policies are employed in operations. However, other than production theory suggests, the task of the directing activity does not simply consist of picking an appropriate combination of elementary factors. The reason for this is that formulating a production function in reality often is not as simple as theory suggests. Furthermore, outcomes, prerequisites, and side effects of different production functions can hardly be estimated. Therefore, the decision subjects’ abilities and their shortcomings have the most profound impact on the performance of the firm.

Cognitive characteristics drift into the centre as the main constraint of production and therefore need special attention, for instance in the ‘theory of constraints’. Cognitive prepositions of decision makers must be seen interlinked with features of the decision situation and the environment of the production process in their effects on decision-making (Simon, 1959). Specifically, the increasing complexity of the competitive arena influences whether decision-making behaviour shows positive or negative results for the operative system. This complexity is caused by various sources, for example legal and governmental actions, social norms and pressures, geographically extended areas of competition (Größler et al., 2006). As research in many scientific areas has demonstrated, human decision-making is only partly able to deal with complexity (Rabin, 1998). If a concept for production management acknowledges the limited abilities of its agents it therefore fulfils an old request of Simon and other authors of the ‘behavioural economics’ school (Simon, 1959). Their claim is an integration of empirically-based evidence about human decision-making into economic theory. With the help of concepts like the ‘theory of constraints’, behaviourally-based operations management can better explain reality in organisations and help to overcome restrictions of human decision-making.

### **Thinking process and decision making in operations management**

Deficiencies in decision-making mainly occur in complex, not in simple decision-making environments (Milling, 2002). Furthermore, sometimes detail and dynamic complexity (Sterman, 2000), or behavioural and dynamic complexity (Roth & Senge, 1996) are differentiated. However, what constitutes a ‘complex situation’ is subjective within a certain range: what is an easy decision to make for an expert might be impossible to comprehend for a novice (Strohhecker, 1998). Nevertheless, there seems to be a certain limit of complexity beyond that even the most skilled expert cannot act fully rationally. It is the major assumption of this paper that many decisions in production and operations management lie beyond this complexity border and, thus, production is a complex setting affecting decision-making. Therefore, it is assumed that the creation and the behaviour of a production system (as well as of the firms as a whole) are determined by the limited rational action of its members (March & Simon, 1993).

Decisions in operations management are determined by the interplay of complexity

with physiological, psychological, and social characteristics of humans (Sterman, 1994). Several barriers exist that limit the amount and quality of data that can be perceived and processed by humans. These limitations are built in the interlinked system of perceptive organs and the nervous system including the human brain (Zimbardo, 1992). Although these issues block us from an enormous amount of data regarding the current situation, they do not play a vital role in the context discussed in this paper, i.e. in managerial decision-making. Nevertheless, they might be important for operative and manual work at the shop floor, for instance when considering the trade-off between speed and accuracy of perceptions (Viale, 1992; Thun et al., 2007). Restrictions of the information processing speed and the storage capacity, which are imposed on individuals by biological characteristics of the brain (Simon, 1978), have bigger influences on decision-making. In manufacturing many situations can be thought of that are potentially hampered by these limitations of decision makers, for instance: people deciding about order sequencing cannot take into account all possible sequences and find the optimal solution; the effects of a machine break down can often not be overseen because there are plenty of side effects; the switch to another production technology cannot be fully comprehended because—again—not all effects can be calculated and not all influencing variables can be considered. Many of these problems can be mitigated with the help of computers applying both, algorithmic procedures and simulation analyses (Pidd, 2004). However, also the promising combination of intuitive human brains and powerful processing of computers (Milling, 1991) often comes to limits when outcomes are uncertain, decision variables are not considered, or their usage is affected by political processes inside the organisation.

Another group of decision-making deficiencies is related to psychological characteristics of humans. In contrast to the limitations discussed in the previous section, these are not simply physiologically determined. Thus, they can—at least in principle—be overcome when decision makers are aware of these flaws, for instance with the help of special trainings (Milling, 1995).

Generally, and also when observing a decision situation, humans show a behaviour called ‘selective perception’ (Hogarth, 1987). This means that not every sensation that reaches the perceptive organs is actually perceived, even when the ‘hardware’ in form of nerves and brain could handle more data. The reasons for this issue are manifold. For instance, the attention of humans usually cannot be directed at many things simultaneously; if an individual’s attention is occupied by something, it might not pay attention to something else, anyway how important this other thing objectively is (Broadbent, 1999). The limited amount of attention leads to an over-emphasising of the current, most accessible line of thinking in individuals (Dörner, 1996). Another reason for ‘selective perception’ is symbolised by the saying ‘you can only see, what you know’. In general, the beliefs, expectations and assumptions possessed by a human being determine what can be perceived (Sterman, 1994). Again, it is possible to list some examples of how these limitations might influence decision-making in a manufacturing context: being too much occupied with shortening cycle times might prevent seeing that machinery urgently needs maintenance; when deciding about

the purchasing of new machinery one might oversee that worker motivation is decreasing; if production does not know about the demands of the final customers they might not see small differences in final products, for instance in colouring. Another form of psychological deficiency concerning decision-making is named 'illusion of control' (Langer, 1975). More generally, it can be stated that humans want to maintain their self concept (Steele, 1988).

Managerial decisions are (nearly) always made in social situations. One can distinguish two meanings of this statement: firstly, decisions are made by groups, and, secondly, even the individual, seemingly independent decision maker is influenced by the social setting of a decision situation. One category of deficiencies occurring when groups make decisions is called 'group think', which means that the group arrives at a decision prematurely (Janis, 1982). But also in the case of an individual's decision, deficiencies can occur, for instance, because a decision maker is watched by others, consulted by others, has a superior, has inferiors etc. There exists influences from various stakeholders that the decision maker has to take into account (Boudon, 1992); hierarchical and power structures in organisations influence how decisions are being made. Again, it is not very demanding to think of examples from manufacturing: when deciding about a shop floor layout, after a very short discussion the production team arrives at a decision being exactly equal to the CEO's idea (who does not know a lot about the basics of production); a production manager avoids to conduct preventive maintenance because this might look to superiors as if the workforce would be underutilised normally; the purchase of an efficient machinery is delayed because it affects the current quarter figures, which would undermine the manager's (current) success record.

Theory of constraints (Theory of constraints) offers starting points to improve managerial decision-making. Before that, however, it should be noted that human decision-making is—in general—quite successful and sensible, particularly in the light of the many potential deficiencies that were described above (March, 1978). Throughout the history of mankind and by education of each individual, humans have acquired a set of strategies and heuristics that in many occasions are reasonable to employ, when a decision has to be made (Gigerenzer & Todd, 2000). However, as research shows there seem to be situations where these otherwise useful methods of the mind are prone to systematic errors (Dörner, 1996). Such situations are identified above as being complex decision-making in production and operations management. The 'theory of constraints' can help to mitigate the potential problems of deficient decision-making in two ways: on a conceptual level and on a methodological level. Conceptually, the 'theory of constraints' makes clear that there are constraints in every production process that represent opportunities for improvement (Rahman, 1998). Thus, the 'theory of constraints' guides thinking, through providing ideas and by stating facts about production processes. A brief review of the most fundamental step-like approach to improve a production system according to the 'theory of constraints' gives further indication supporting this argument (Goldratt, 1990).

Besides the general approach of the 'theory of constraints', particularly the so called 'thinking process' can help to mitigate potential fallacies of decision-making (Kim et al., 2008; Goldratt, 1994). The 'thinking process' was created as a reaction to the fact



that managerial decision-making constraints gained importance in comparison to physical shop floor constraints (Rahman, 1998). The methods comprised in the ‘thinking process’ are supposed to support management in deciding about necessary change. In particular, it should help regarding the following issues: (1) deciding what to change, (2) deciding what to change to, and (3) deciding how to change. For this end, five forms of cause-and-effect diagrams are described: ‘current reality trees’, ‘evaporative clouds’, ‘future reality trees’, ‘prerequisite trees’, and ‘transition trees’. With the help of these instruments, problems can be identified and practical solutions to these problems can be found and implemented. Cause-and-effect relationship help to diminish issues from all three areas of potentially deficient decision-making: load on the working memory is reduced; attention can be directed to the causes of problems, not the symptoms; mental models of decision makers become ‘explicit’ and are therefore easier to change; criticism can focus on issues, not on people.

### **The relationship between the ‘theory of constraints’ and ‘system dynamics’**

There exists a relationship between theory of constraints and system dynamics (Forrester, 1961; Sterman, 2000). Theory of constraints is based on a well-known principle from system dynamics and that it uses methods which are similar to ones that are applied in system dynamics studies. In other words, the intersection of ideas and methods between Theory of constraints and system dynamics is substantial. Indeed, various authors have reported on possibilities to combine the ‘theory of constraints’ with system dynamics (Balderstone, 1999; Davies et al., 2004; Cox et al., 2005; Mabin et al., 2006) or compared the two approaches in their effectiveness for problem-solving (Musa et al., 2005). The notion that a constraint exists in every production system is in accordance to the ‘limits to growth’ archetype as identified in system dynamics: there is always a limitation to indefinite growth of a system (Meadows et al., 1972). Also, the recommendations are similar: “Don’t push on the reinforcing (growth) process, remove (or weaken) the source of limitation (Senge, 1990)”. Dettmer (1997) emphasised this systemic approach of the ‘theory of constraints’. Like system dynamics, the ‘theory of constraints’ proposes that there are many advantages of using formalized ways to diagram production systems: hypotheses about causal linkages can be stated in a formalised, but easy to understand way; mental models of individuals and groups can easily be elicited; they offer the possibility to evaluate, discuss and criticise assumptions that underlie decisions; because of the necessary simplification inherent in all modelling approaches discussions can focus on the relevant issues.

Senge (1990) emphasised feedback as a structural element that most decisional situations comprise and which fundamentally determines the behaviour of a system. However, the identification of feedback loops is still not a common task in many cause-and-effect diagram techniques, for instance in the ‘thinking process’. In contrast to that, theory of constraints’s cause-and-effect diagrams put more emphasis on the implementation of solutions and on the consideration of power structures within organisations, two areas sometimes identified as problematic within system dynamics (Größler, 2007; van der Smagt, 2006; Snabe and Größler, 2006). Potential fallacies of cause-and-effect diagrams in general are discussed in Richardson (1986).

As system dynamics, theory of constraints does not promise an optimal solution but a satisfying and reasonable one. With the help it provides for overcoming deficiencies of human decision-making, the ‘theory of constraints’ has its foundation in the observation of real world situations. Thus, like system dynamics it does not pose many assumptions on the nature of its agents but accepts individual and organisational shortcomings (Größler, 2004). Although it is not aiming for optimality, the ‘theory of constraints’ is nevertheless able to offer some prescriptive guidelines and to help practitioners in complex decision situations, similar as system dynamics does.

## Results and Discssion

It has been found that decision-making in operations management is prone to systematic failures because operations is a complex environment. The ‘theory of constraints’ as well as system dynamics offer ways to mitigate or to prevent some of these failures. Theory of constraints and system dynamics have a substantial overlap of common goals, concepts, and methods. In the broader operations management context, the three main challenges can be derived from the findings. Firstly, that the concept of limited rational decision-making should find its way into standard operations strategies and procedures. Secondly, managerial policy and decision-making should be supported by organisational and technical means to mitigate presumably negative effects of cognitive biases, and lastly both, the ‘theory of constraints’ and system dynamics should concentrate on and extend their competence in providing means to handle limitations of managerial decision-making.

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