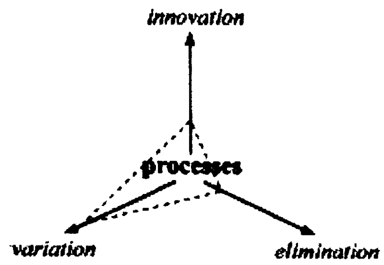
南華大學九十三學年度 博士班 招生考試試題卷

系所別：管理科學研究所	科目編號：C2-01-01
科　目：管理論文評析(一)　【第一篇 / 共二篇】	試題紙第 1 頁共 10 頁

管理論文評析(一)
(請用中文回答下列各題，否則不予計分)

1. 試**分別說明**本文之研究動機以及主要貢獻為何？(10 分)

2. (a) 本文中提及 "products"、"processes"以及 "resources"，試問此三者對 "strategic production decisions" 所扮演的主要角色為何？(5 分)
   (b) 參看本文敘述後請說明下圖虛線所代表的意涵。(5 分)



3. 請說明本文所提之 "Operator nets" 與 "Petri nets" 的不同點。(10 分)

4. (a) 參考圖 4 與下列式子，試寫出圖 4 中 "udpc" 與 "uc" 之數學式

$$\text{pcr} = \frac{\left(\sum \text{sustf}_i \cdot c_i / pv\right) + \sum \text{consf}_i \cdot r_i}{\sum q_i \cdot \text{lt}}$$ (5 分)。

   (b) 試說明本文第 6 節中 $\overline{\text{PVI}}$ 的計算方式為何權數的分配為 $(\frac{1}{6},\frac{4}{6},\frac{1}{6})$。(5 分)

5. 根據本研究的 "A short case study"，其中除現行策略外，另有兩修訂策略，請**將此三策略的好壞依量化後的指標值進行排序**，並結論此個案生產系統的改進方向為何。(10 分)

ELSEVIER

Int. J. Production Economics 69 (2001) 119–127

international journal of production economics

www.elsevier.com/locate/dsw

Valuation of strategic production decisions

Axel Brassler*, Herfried Schneider☆

Technical University of Ilmenau, Department of Production Management, P.O. Box 10 05 65, D-98684 Ilmenau, Germany

Received 30 March 1998; accepted 5 November 1999

Abstract

The value chains in industry need to be competitively organised to enable them to meet market expectations. This involves identifying the critical strategic decisions for production and subjecting them to a valuation process to establish their economic effectiveness. It is obvious that strategic production decisions include many valuation problems. In the first place, a production system is a widely branching value chain with many interrelations. Changes in one area have effects in other areas. Secondly, in production, one never makes an isolated strategic decision. It will always be a bundle of interconnected measures. To tackle both problems at once, it might be useful to represent the production processes by a model, based on petri nets. With their help one can achieve an overall schematic representation of linked production processes, in which the input data can be derived from the case in point. The model is capable of evaluating alternative production strategies. Real situations and potentials decisions can be represented. Their effect on the production system will be calculated and an economic analysis provided. The data output from the model can be combined with external data from market sources so that a process value indicator (PVI) is derived. The PVI is then a performance indicator for both current and potential production systems. Its value can be used mathematically as an aggregated figure in valuation and decision-making. © 2001 Elsevier Science B.V. All rights reserved.

Keywords: Model design; Strategic production decision; Petri net theory; Process value indicator; Ratio system; Decision making

1. Introduction

The goal of strategic production planning is to fine-tune the production system to meet the demands of the market in the most competitive way possible. It is common practice to develop a production strategy, as a "projected pattern of manufacturing choices formulated to improve fundamental manufacturing capabilities, and to support business and corporate strategy" as Miller and Hayslip put it [1]. The decisions required are often judgements taking into account *uncertainty as to market trends* and the needs for both *intensive utilisation of resources* and *long-term effectiveness*. Given that predicting the results of strategic production decisions will always be difficult, this paper offers a general approach to obtaining better information so that the best of the possible strategic decisions can be selected.

Strategic decisions are put into practice by means of tactical measures which are, again, the basis for changes in operative production processes [2].

* Corresponding author. Tel.: + 49-3677-694010; fax: + 49-3677-694201.

E-mail addresses: axel.brassler@wirtschaft.tu-ilmenau.de (A. Brassler), herfried.schneider@wirtschaft.tu-ilmenau.de (H. Schneider).

☆ The authors are grateful to two anonymous referees for their valuable comments.

PII: S0925-5273(99)00135-8

The chain reaction implicit in this statement suggests the usefulness of representing the operations of a production system by a model. Using the model, the intention would be to establish the connections and what the effects on operative changes actual decisions would have.

2. Strategic production decisions

One can analyse strategic production decisions along various lines. The term "production" itself includes not only the manufacturing system. Even starting with order acceptance (and ignoring, as our model must, the market research stages or R&D) it will be necessary to take into consideration the product design, production planning and logistics as well.

In other words, the production system has to be regarded as the whole value-added process. To improve the competitiveness of the production system, the categories *products*, *processes* and *resources* are all potential objectives for alteration (see Fig. 1).

Every intermediate result within the value-added process can be viewed as "products". For this reason the "*products*" area does not only include the physical products (goods). Internal services, e.g. the product design or production plans can also be regarded as "*products*", which can be traced back as intermediate results within the value added process.

The "*resources*" area contains the technical equipment (machines, computers, handling systems, etc.) and the human resources. Both the technical and human aspects are necessary to produce the "*products*" mentioned above.

In order to bring the "*products*" area and the "*resources*" area together, the third area affected, the "*processes*" area, is required. Each of the processes consists in a repeatable result from concatenated sub-activities with a measurable input, a measurable value added and a measurable output.

Within the areas affected by the overall decisions there are three alterations that are basically possible.

- Firstly one can completely *innovate* the different categories. For example, one could launch a new product or purchase a flexible manufacturing system.
- The second possibility is to *vary* the areas affected. For example, to modify several product features or to change production processes.

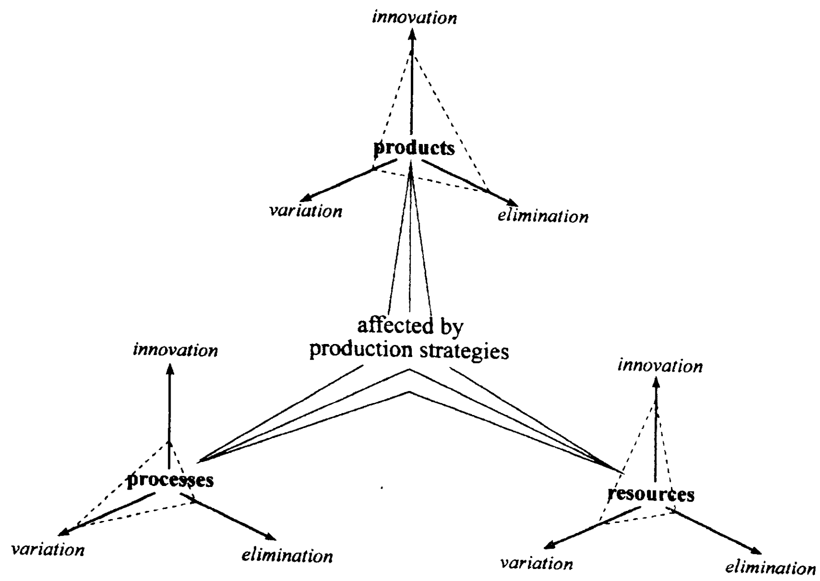


Fig. 1. Areas affected by production strategies.

- Finally, complete *elimination* is also possible. For example, the elimination of products as a whole or of components and technologies by reducing the depth of in-house production. Under this heading, the change does not involve replacement because the elements are eliminated.

To summarise, strategic decisions in production systems will either vary, innovate or eliminate "*products*", "*processes*" and/or "*resources*", which are the areas affected over time.

Such changes will require the particular features of strategic production decisions to be highlighted. The difficulty of predicting what results to expect from strategic production decisions arises from the following two basic problems:

(a) A strategic production decision within one "area" (*p/p/r*) affects the other "areas". The introduction of a new product is associated with, for example, investment in new machines and the changing of logistic processes. This means that a strategic production decision is never an isolated decision. It is always a "bundle of measures" with strong interrelations.

(b) Besides the basic manufacturing process, there are many supporting processes in production systems, e.g. order procedures, product design, PPC, logistics, etc. Production is, indeed, a widely branching value chain with a high degree of interdependence. Here again, changes in one part of the network have effects in other parts.

Strategic production decisions as "bundled action programmes" on one hand and a widely branching process network on the other hand are what makes it difficult to foresee the potential of alternative production plans. A model could well be a valuable means of judging such strategic decisions. This model should be capable of integrating the *products, processes* and *resources* areas and of expressing the potential dynamic behaviour of the various systems quantitatively, e.g. *time required, input of production factors necessary* and *quality achieved*. The crux is to integrate only such features into the model as can be measured originally in the production process.

There are certain external criteria or given data, which have to be generated outside the model, e.g. market prices or sales volume. These must be reintroduced to the model at the conclusion, in a ratio system.

In the next section the design of the model will be considered.

3. Model of a production system, using Petri-net-theory

The concept of "operator nets" is applied both in the modelling and the analysis of the production system. This method combines Petri-net-theory with stochastic network planning (GERT) and is a convenient means of representing dynamic processes.

In 1962 C.A. Petri laid the foundations of a general net theory as an approach to modelling and analysing communication systems [3]. Since 1962 Petri nets have been developed further and have been applied in several areas. They have proved to be very useful in particular in the modelling, analysis and simulation of manufacturing systems. According to Desrochers and Al-Jaar Petri nets are useful for the following reasons [4]:

- Petri nets are based on a well-developed mathematical and practical foundation which gives a structured framework for carrying out a systematic analysis of complex systems, for example reachability, boundedness, liveness and deadlock.
- These nets are capable of representing the precedence relations and structural interactions of stochastic, concurrent and asynchronous events.
- Their graphical nature enables very large and complex systems to be visualised.
- Conflicts and buffer sizes can be designed easily and efficiently.

Fig. 2 shows an ordinary Petri-net. It is a bipartite-directed graph which has two types of nodes called places and transitions. To connect these two types of nodes one can use directed arcs. They always join places to transitions or vice versa. A directed arc never joins a place to a place or a transition to a transition. To represent the dynamics of a system

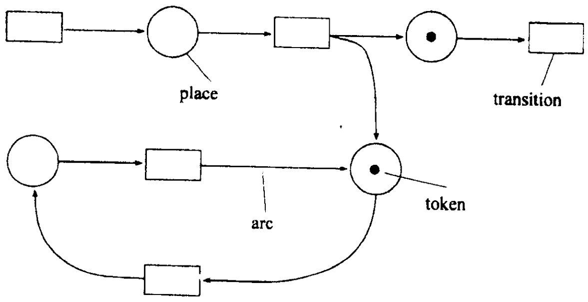


Fig. 2. An ordinary Petri-net.

each place contains one token which is represented graphically by dots. The dots or tokens travel along arcs, and their flow through the net is regulated by transitions.

Formally, an ordinary Petri-net is a quadruple $PN = (P, T, A, M_0)$, where

$P = \{p_1, \ldots, p_n\}$ is a finite set of *places*,

$T = \{t_1, \ldots, t_m\}$ is a finite set of *transitions*,

$A \subseteq (P \times T) \cup (T \times P)$ is a finite set of *arcs*,

$M_0: P \to \{0, 1\}$ is the initial marking.

For the requirements of a production model we have to take some useful extensions into consideration. "Operator nets", which can be identified as a special class of *coloured stochastic timed Petri nets*, include these extensions, which are:

- integrating time into Petri-nets by introducing a deterministic delay after a transition has been enabled [5].
- considering stochastic influences by a representation of the transition times with random variables [6].
- allowing each place to contain more than one token [7].
- using colours to differentiate the tokens [7].
- furnishing coloured tokens with data sets which allow the integration of quantity features.
- integrating the logical operators 'OR' and 'XOR' into the places and transitions, as it is a weakness of ordinary Petri-nets that they only have logical combination and branching using 'AND'.

With these extensions, Petri nets offer a convenient way of representing production processes and will henceforward in this text be called "operator nets".

Fig. 3 shows a process-oriented production model using an "operator net". As one can see, a production process is a set of interrelated activities which, when executed, results in a process outcome. The process outcome is modeled by coloured tokens i.e. the different orders. The different activities required to process the orders ("process elements") are represented by transitions. When the process model is in operation, the tokens flow through the net and show the processing going through its various stages. For the model to represent the quantitative behaviour of a process, it is necessary to integrate the features *time*, *quality assurance mechanisms* and other *production resources applied*.

The quality assurance mechanisms can be shown by loops linking the relevant transitions. If the quality achieved has to be rejected, the relevant token returns to the appropriate transition. In that case, *time* and the *resources applied* need to be taken into account once again.

The resources applied can be divided into two separate categories. For each process element it is possible to identify two types of factor: those on the one hand which are necessary to the general existence of the process (sustaining factors) and those on the other hand which are exhausted by the process itself (consuming factors).

These resources, whether consuming factors or sustaining factors, are measurable both at the input and outcome stage of the process simulation. At the outcome stage the consumption of consuming factors, the level of capacity utilisation for each process element, and the actual production figures will be apparent. Likewise, time is an input feature and there are measurable outcomes: incl. lead times, processing times, transfer times and turnround times.

4. A valuational approach using the process model

A "process model", represented by an operator-net, is capable of demonstrating the dynamic behaviour of production systems. At the end of the simulation one receives details of all the features mentioned above (whether consuming/sustaining factors, time feature, or quality criteria).

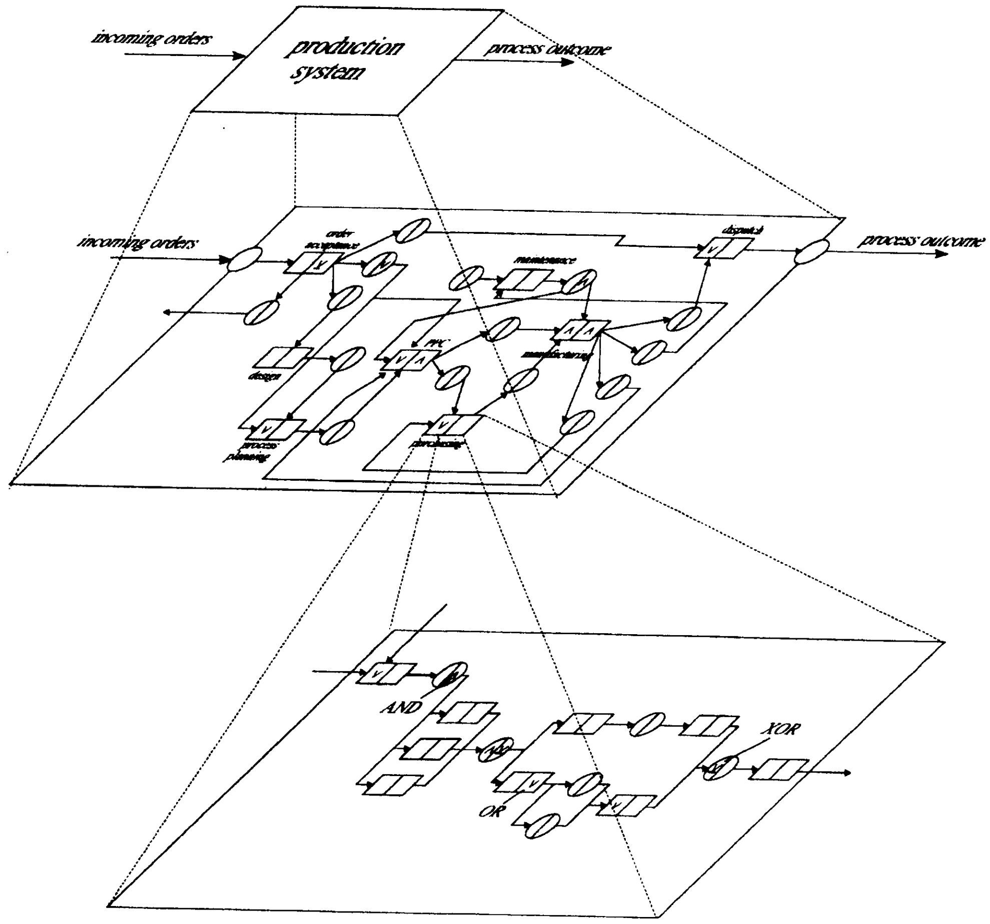


Fig. 3. Process model using an operator net.

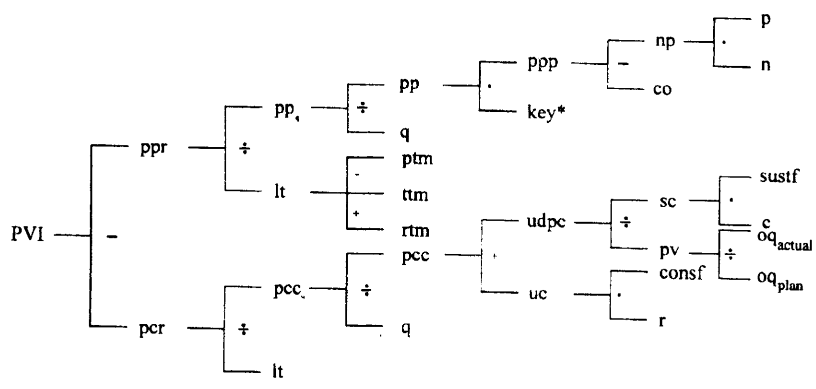


Fig. 4. The process value indicator.

All the details at the output stage must be somehow combined in order to facilitate statements about the overall performance of the production system which has been modelled. One possible choice is to unite them in one single ratio, which can be called *process value indicator* (PVI) and will serve as an indicator of the value or degree of efficiency of the production process. The ratio to be known as the PVI will be derived from all the correlated details as represented in Fig. 4. note the computational relations in the illustration.

It goes as a general principle, the higher the PVI, the better the process. The PVI can be computed by subtracting the *process cost rate* (pcr) from the *process performance rate* (ppr). The *process performance rate* is obtained by dividing the *average process profit per unit* (pp_q) by the *lead time* (lt), and the *process cost rate* (pcr) is obtained by *average process cost per unit* (pcc_q) divided by *lead time* (lt).

Thus the *process value indicator* may be expressed by the following formula:

$$\mathrm{PVI} = \frac{\mathrm{pp}_q - \mathrm{pcc}_q}{\mathrm{lt}},$$

where PVI *is the Process Value Indicator*, pp_q *the average process profit per unit*, pcc_q *the average process cost per unit, and* lt *the lead time.*

As the equation makes clear, the PVI is the quotient derived from relating the profits (being the difference between proceeds and costs) to a figure for time. Therefore, it is possible to improve the PVI if either the lead time can be reduced or the excess of proceeds over costs can be increased. Another way of expressing this is, of course, that the value of the process can only be improved if more profit can be achieved within the original period of time or if a shorter time is required to achieve the same profit.

To go back to the initial formula, the *process performance rate* (ppr) is a function of the *lead time*, which is the sum of the *processing time* (ptm), *transfer time* (ttm) and *turn-round time* (rtm). All these are individually identified in the outcome of the simulation. In contrast to these features computed within the model, the average *process profit per unit* (pp_q) comes from outside the process model, as it is the *process profit* (pp) divided by *the number of units of output over the period specified* (q). To obtain the *process profit* (pp) it is necessary to multiply the *production process profit* (ppp) by a key. The key will be 1 if the PVI is to be computed for all production processes, and less than 1 if the PVI is intended to express the economic performance level only for a part of the value added process. The ppp is the difference between the *net profits* (np) and the *overheads* (co). The *np* can be computed by multiplying (p), the *price per unit* by (n) *the number of items* actually produced. To summarise, the *process performance rate* can be expressed by the following formula:

$$\mathrm{ppr} = \frac{(\sum p_i n_i - \mathrm{co}) \cdot \mathrm{key}^*}{\sum q_i \cdot \mathrm{lt}},$$

ppr *is the process performance rate*, key* *the process key*, p_i *the price per unit for the kind of product i*, lt *the lead time*, n_i *product i, number of items*, q_i *the complete output, and* co *the cost of overhead.*

Turning to the pcr, the *process cost rate*, the lead time will be already known. However, further steps are required to determine the *process cost rate*, which is affected by *sustaining factors* (sustf) and *consuming factors* (consf). Both these features do have to be derived by simulation, using the process model.

The *process cost rate* can be computed by means of the following equations:

$$\mathrm{pcr} = \frac{(\sum \mathrm{sustf}_i \cdot c_i/pv) + \sum \mathrm{consf}_i \cdot r_i}{\sum q_i \cdot \mathrm{lt}}, \quad pv = \frac{oq_{\mathrm{actual}}}{oq_{\mathrm{plan}}}.$$

pcr *is the process cost rate*, lt *the lead time*, sustf *the sustaining factors*, *c the cost rate of sustaining factors*, consf *the consuming factors*, *r the cost rate for consuming factors*, *pv the level of capacity utilization*, oq_{actual} *the current capacity utilization*, *q the complete output, and* oq_{plan} *the planned capacity.*

The *process value indicator* thus computed is an aggregated ratio expressing how well a production system works. The next thing is to look at using the PVI for the valuation of strategic production decisions.

5. A general three-step approach for valuating strategic production decisions

Once the real production system has been represented by means of operator nets, it is possible to compute the features of the process model by simulation, and calculate the PVI from the outcome. Now the effects of alternative strategic production decisions can be seen by comparing how they affect the process model.

The tactical measures involved in strategic decisions will in turn be responsible for changes in the way the production processes operate. This means clarifying all the tactical decisions and making the necessary changes to the process model, which will only be possible by looking at which process elements require changes to their parameters, which process elements can be eliminated and whether new process elements and relations must be introduced. In effect, the process model has to be redesigned to reflect how new strategic decisions will have process changes associated with them. For the valuation one can take the following procedure.

5.1. Simulation under certain expectations

After the *process model* has been modified with the new input, it is possible to simulate the changes in the behaviour of the production system arising from alternative strategic decisions. The results can be aggregated to the PVI expressing the new situation. The alternative with the highest value for the PVI can be regarded as the best one.

The main point is to accept definite expectations in this case – a condition which does not exist in the second step.

5.2. Risk analysis

To allow for an uncertain future, it is possible to set up a process model for different scenarios. The most useful will be the best case scenario, the basic case and the worst case. When the different situations have been modelled, the PVIs can be computed again. The different PVIs can be multiplied by the probabilities, if these are available for each situation. These weighted PVIs can be added together to give the *process value under uncertainty*.

5.3. Scoring analysis

The exactly measurable data are not the only features which are important for strategic production decisions and must be taken into consideration: soft facts are important as well, e.g. flexibility, job satisfaction, etc. In the literature a procedure known as *scoring analysis* is available to take the soft facts into account, and it can be usefully combined with the PVI scoring model. Finally, one obtains a numerical value which indicates the best alternative.

6. A short case study

A case study has been carried out on the manufacture of electric motors, with the aim of reorganising the production system. The intention was to improve production both by installing new machinery and altering the supply chains.

The initial situation (to be called A_0 a "basic case") before input into the model is represented in Table 1. All data from the case study were greatly simplified for the table.

Obviously, such a short table involves some summarising and modification. However, its main purpose is to represent the basic procedure for PVI computation.

Computation of the average process profit per unit (pp_q):

$$pp_q = \frac{(\sum p_i q_i - co) \cdot key^*}{\sum q_i}$$

$$pp_q = \frac{((80.000 \cdot 151 + 110.000 \cdot 68) - 3.750.000) \cdot 0.8}{151 + 68}$$

$$= 57{,}753.42$$

Computation of the average process cost per unit (pcc_q):

$$pcc_q = \frac{(\sum sustf_i \cdot c_i / pv) + \sum consf_i \cdot r_i}{\sum q_i},$$

$$pcc_q = \frac{(8.427.510/0.947916667) + 2.651.463}{219}$$

$$= 52{,}703.30.$$

Initial situation as computed are given in Table 2.

Table 1
Quantitative data

Abbr.	Data	Type of unit	Comment
Specified period	3	Months	
p_A	80.000,-	Money units	Price of one ordinary electric motor (product A)
p_B	110.000,-	Money units	Price of one special electric motor (product B)
q_A	151	Unit	Number of items ordered (product A)
q_B	68	Unit	Number of items ordered (product B)
co	3.750.000,-	Money units	Cost of the general management processes
Key*	0,8	—	80% of the value added should be achieved in the system under investigation
lt	3,6	Days	Average lead time for both products
sustf1	910	Hours	Capital allowance (calculated in hours)
c1	5678,-	Money units	Cost per hour (capital allowance)
sustf2	910	Hours	Room costs (calculated in hours)
c2	2349,-	Money units	Cost per hour (room costs)
sustf3	910	Hours	Labour (calculated in hours)
c3	1234,-	Money units	Average hourly salary, load conditions as planned
consf 1	720	Units	Material, type 1
r1	290	Money units	Cost per unit of the type 1 material
consf2	2515	Units	Material, type 2
r2	673	Money units	Cost per unit of the type 2 material
consf3	1028	Units	Material, type 3
r3	360	Money units	Cost per unit of the type 3 material
consf4	1324	Units	Material, type 4
r4	287	Money units	Cost per unit of the type 4 material

Table 2

A0	Basic case	Worst case	Best case
pp_q	57,753.42	56,975.61	58,689.36
lt	3.6	3.58	3.78
pcc_q	52,703.30	55,595.64	50,060.07
ppr	16,042.61	15,914.97	15,526.28
pcr	14,639.80	15,529.50	13,243.40
PVI	1,402.81	385.47	2,282.88

The current situation (A_0) was also represented for a less productive period (worst case) and an extremely good one (best case). In order to express the initial situation by a single PVI, the computed results for each of the three cases were combined in a symmetrical distribution:

$$\overline{\text{PVI}} = \frac{385.47 + 4 \cdot 1402.81 + 2282.88}{6} = 1379{,}9317.$$

With the intention of improving the situation, we constructed the process model around two alternative new strategies. In the first model (A_1) we replaced some problematic machines and also altered the flow of material. In a second model (A_2) we vastly increased the level of automation.

The PVI results for the two strategies are shown in Tables 3 and 4.

7. Conclusions

As has been shown, operator nets offer a useful way of modelling production processes, and deriving the *process value indicator* by computation. This indicator can be regarded as an aggregated ratio for expressing the quality of the production system's behaviour, and permits the potential outcomes of different strategic production decisions to be compared.

For a given situation to be simulated and the associated PVI calculated, it will be necessary not

Table 3
$\overline{PVI}_{A1}$ = 1523,99

A1	Basic case	Worst case	Best case
pp_q	57,753.42	56,975.61	58,689.36
lt	2.8	2.4	3
pcc_q	53,637.00	56,005.71	50,111.72
ppr	20,626.22	23,739.83	19,563.12
pcr	19,156.07	23,335.71	16,703.90
PVI	1,470.15	404.12	2,859.21

Table 4
$\overline{PVI}_{A2}$ = 1134,4883

A2	Basic case	Worst case	Best case
pp_q	57,753.42	56,975.61	58,689.36
lt	1.9	1.7	2.2
pcc_q	55,644.67	56,865.65	53,623.26
ppr	30,396.53	33,515.06	26,676.98
pcr	29,286.66	33,450.38	24,374.20
PVI	1,109.87	64.68	2,302.77

only to have full input data but also to modify the parameters of the model or its design. With these combinations one has a reliable information basis for deciding between different production strategies.

References

[1] J.-G. Miller, W. Hayslip, Implementing manufacturing strategic planning, Planning Review 17 (4) (1989) 22–48.

[2] H. Mintzberg, The Rise and Fall of Strategic Planning, Reconceiving Roles for Planning, Plans, Planners, Free Press, New York, 1994.

[3] C.A. Petri, Kommunikation mit Automaten, Ph.D. Dissertation, University of Bonn, Germany, 1962.

[4] A.-A. Desrochers, R.-Y. Al-Jaar, Applications of Petri Nets in Manufacturing Systems, Modelling, Control, and Performance Analysis, Alan A. IEEE Press, New York, 1995.

[5] C. Ramchandani, Analysis of asynchronous concurrent systems by Timed Petri Nets, Ph.D. Thesis, Massachusetts Institute of Technology, Cambridge, MA, 1973.

[6] M.-K. Molloy, On the integration of delay and throughput measures in distributed operating models, Ph.D. Thesis, University of California, Los Angeles, 1981.

[7] K. Jensen, Coloured Petri Nets, Lecture Notes in Computer Science, vol. 254, Springer, Berlin, 1987, pp. 248–299.