PORTFOLIO APPROACH FOR INVESTMENT PLANNING OF PRODUCTION EQUIPMENT

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ABSTRACT
A new investment planning method is proposed to determine purchase of suitable production equipment considering demand fluctuations by using portfolio for manufacturing systems consisted of CNC machine tools and jobs in this research. The portfolios are set to consider candidates of the purchasing production equipment for investment.

Returns and risks considering demand fluctuations of the individual portfolios are required in order to select the best portfolio in the proposed investment planning method. The returns and the risks of the portfolios are calculated under assumptions that candidate production plans and probabilities that correspond to demand have already been obtained. Estimated profit is required to calculate the returns and the risks of the individual portfolios. The profit is estimated based on the cases where the production plans are carried out by using the purchased production equipment and existing equipment.

Evaluation method of the obtained portfolios is also proposed based on information ratio in this paper.

INTRODUCTION
Investment planning of production equipment is one of important decision making for manufacturing systems which aim to maximize profit. Future demand and its uncertainty have to be taken into account for considering the equipment investment of the manufacturing system. The uncertainty of the demand have a direct impact on the effect of capital investment, it means that investment of production equipment involves a risk of demand fluctuations.

Following researches have been carried out for investment planning considering demand fluctuations.

Achim Kampker et al.(2013) proposed strives for a systematic and economic measurement of flexibility in investment decisions. Due to fast changing market requirements and short product life cycles, flexibility is one of the crucial characteristics. It offers methods and key-figures supporting the investment decisions for automated assembly systems. The right levels of flexibility and automation of an assembly system are evaluated by using a set of potential future scenarios of the system’s life cycle. Based on two new key-figures called Return on Automation and Return on Flexibility, the approach allows comparing different configurations of an assembly system and therefore supports well-informed investment decisions.

Investment decisions for manufacturing systems are primarily based on three characteristics: cost of purchase and operation, cycle time in connection with maximum capacity and achievable work piece quality. However, E. Abele et al.(2006) states that such considerations neglect another important criterion: the flexibility that allows a manufacturing system to adapt to future production requirements and structures. The major barrier in integrating flexibility into the decision-making process is the difficulty to measure and compare it due to upcoming production scenarios that are not ultimately definable.

Therefore, a methodical concept is proposed for the evaluation of manufacturing systems using real options in order to incorporate flexibility in the decision-making process.

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**Target Manufacturing Systems for Investment Planning**

Figure 1 shows the target manufacturing systems which consists of CNC machine tools of individual types and jobs to propose the investment planning method in this research. Following conditions are assumed to propose the investment planning method considering fluctuations in demand.

- Candidate production plans have already been determined in a given period. Production plans gives the types of products and amount of production of them. It means that product mixes are different according to individual candidate production plans.
- Probabilities that candidate production plans correspond to demand have already been estimated.
- Only machining processes are considered for the target manufacturing systems. Required machining processes of individual jobs and their processing time have already been determined.
- The machining processes executed by machine tools of each type are different.

**Generation of Candidate Portfolios and Calculation of Risks and Returns of Candidate Portfolios**

The portfolios are calculated based on procedure (1), (2) by using following symbols for proposed investment planning method.

- \( l \) : ID of portfolio \((l = 1, 2, ..., L)\)
- \( k \) : Types of machine tools \((k = 1, 2, ..., K)\)
- \( n_k \) : Purchased quantity of machine tools of type \( k \)
- \( N_l \) : Combination of \( n_k \) \((k = 1, 2, ..., K)\) in portfolio \( l \)
- \( N \) : Set of all candidate portfolio \( N_l \)
- \( \mu_{nk} \) : Return in the cases where \( n_k \) machine tools of type \( k \) are purchased
- \( \sigma_{nk} \) : Risk in the cases where \( n_k \) machine tools of type \( k \) are purchased
- \( c_{rs} \) : Price of a machine tool of type \( k \)
- \( B \) : Budget limit for investment
- \( \mu_l \) : Return of portfolio \( l \)
- \( \sigma_l \) : Risk of portfolio \( l \)

(1) Generation of candidate portfolios

Set of all the candidate portfolios \( N \) are generated under budget constraint given by following equation.

\[
\sum_{k=1}^{K} c_{rs} n_k l \leq B \quad \text{for all} \quad l
\]

(2) Calculation of return and risk for individual portfolios

Return and risk of combination of \( n_k \) in portfolio \( l \) are calculated after all the candidate portfolio \( N \) are obtained by procedure (1). The machining processes executed by machine tools of each type are different in this research. It means that investment effect of machine tools of individual types have no influence on each other. Therefore, coefficients of correlation become 0 for calculation of risk and return. Risks and returns of combination of \( n_k \) in portfolio \( l \) are given by following equations.

\[
\mu_l = \frac{\sum_{k=1}^{K} \mu_{nk} n_k}{\sum_{k=1}^{K} n_k} \quad \text{for all} \quad l
\]

\[
\sigma_l = \sqrt{\sum_{k=1}^{K} \mu_{nk}^2 n_k^2 / \sum_{k=1}^{K} n_k^2} \quad \text{for all} \quad l
\]

**Calculation of return and risk considering demand fluctuations**

It is required to calculate the return \( \mu_{nk} \) and the risk \( \sigma_{nk} \) for the cases where the \( n_k \) machine tools of type \( k \) are purchased in order to calculate the return \( \mu_l \) and the risk \( \sigma_l \) of portfolio \( l \) by using equations (2) and (3). Generally, Return and risk are represented by average of return in the past and standard deviation of return in the area of management engineering.

Following 4 STEPs are proposed to calculate return \( \mu_{nk} \) and risk \( \sigma_{nk} \) considering demand fluctuations for the cases where the \( n_k \) machine tools of type \( k \) are purchased.

**STEP1 : Setting of initial conditions**

Following symbols are defined to set initial conditions for calculation of return \( \mu_i \) and risk \( \sigma_i \).

- \( i \) : Types of products \((i = 1, 2, ..., I)\)
- \( j \) : ID of candidates of production plan \((j = 1, 2, ..., \pi)\)
- \( v_i \) : Selling price of product \( i \)
- \( a_{ij} \) : Amount of production of product \( i \) in candidate production plan \( j \)
- \( cm_i \) : Material cost of product \( i \)
\( t_i \): Total processing time executed by machine tool of type \( k \) for product \( i \)
\( m_k \): Total quantity of machine tool of type \( k \) before investment
\( c_{ek} \): Electric bill of machine tool of type \( k \) per hour
\( c_s \): General administration cost except electric bill
\( c_l \): Labor cost. One labor is required to operate one machine tool in this research.
\( u \): Borrowing period
\( v \): Interest rate
\( w \): Tax rate

STEP2: Calculation of profit in current term
Profit \( N_I^j \) in current term is estimated based on following equations for the case where candidate production plan \( j \) is carried out.

Profit in current term
\[ N_I^j = OROIDP_j - PT_j \] (4)
Profit tax
\[ PT_j = ORP_j w \] (5)
Ordinary profit
\[ ORP_j = OP_j - IE_j \] (6)
Interest cost
\[ IE_j = v \sum_{k=1}^{K} c_{rk} n_k \] (7)
Business profit
\[ OP_j = GM_j - CS_j \] (8)
Gross operating income
\[ GM_j = S_j - CG_j \] (9)
Amount of sales
\[ S_j = \sum_{i=1}^{I} \nu_i a_{ij} \] (10)
Cost of sales
\[ CG_j = CL_j + CM_j + D_j \] (11)
Cost of labor
\[ CL_j = c_{lj} \sum_{k=1}^{K} t_{ik} a_{ij} \] (12)
Cost of material
\[ CM_j = \sum_{i=1}^{I} c_{mj} a_{ij} \] (13)
Cost depreciation
\[ D_j = \sum_{k=1}^{K} c_{rk} n_k / u \] (14)
General administration cost
\[ CS_j = CE_j + cs \] (15)
Electricity expense
\[ CE_j = \sum_{i=1}^{I} \sum_{k=1}^{K} c_{ek} t_{ik} a_{ij} \] (16)

STEP3: Calculation of investment effect
Investment effect is calculated based on the profit in current term in the case where the candidate production plan \( j \) is carried out by using the purchased production equipment and existing machine tools. Investment effect \( DT_{jk} \) is given by following equation for purchasing \( n_k \) machine tools of the type \( k \).
\[ DT_{jk} = (N_I^j - N_I^j) / N_I^j \] for all \( j, k \) (17)
\( N_I^j \): Profit in current term in the case where candidate production plan \( j \) is carried out by using only existing machine tools (\( n_k = 0 \)).
\( N_I^j \): Profit in current term in the case where candidate production plan \( j \) is carried out by using the purchased \( n_k \) machine tools and existing \( m_k \) machine tools.

STEP4: Calculation of return and risk of portfolio
Equations (18) and (19) are defined to calculate returns \( \mu_{n_k} \) and the risks \( \sigma_{n_k} \) for purchasing \( n_k \) production equipment considering demand fluctuations. The returns \( \mu_{n_k} \) and the risks \( \sigma_{n_k} \) are defined based on the averages and the standard deviations of investment effect \( DT_{jk} \) obtained by STEP3.
\[ \mu_{n_k} = \sum_{j=1}^{J} \pi_j DT_{jk} \] for all \( k \) (18)
\[ \sigma_{n_k} = \sum_{j=1}^{J} \pi_j \sqrt{DT_{jk}^2 p_j - \mu_{n_k}^2} \] for all \( k \) (19)

EVALUATION OF PORTFOLIO
Following 2 steps are proposed in order to select the best portfolio based on the return and risk calculated by equation (2) and (3).

step 1 Removing of portfolios whose returns are negative
The portfolios are removed from candidate portfolios in the case where the portfolios are not satisfied following equation.
\[ \mu_i \geq 0 \] (20)
Investment of machine tools is not executed if all candidate portfolios are not satisfied equation (20).

step 2 Selection of best portfolio by using information ratio
The Information ratio is a measure of the risk-adjusted return of a financial security. The information ratio is given by Eq. (21) which represents a ratio of portfolio returns above the returns of a benchmark to the volatility of those returns.
\[ IR = \left( \frac{R_p - R_i}{\sigma_{p-i}} \right) \] (21)
where,
\( R_p \): Return of the portfolio
\( R_i \): Return of the benchmark
\( \sigma_{p-i} \): Standard deviation of the difference between returns of the portfolio and the returns of the index
It is assumed that return of the benchmark \( R_i \) equal 0.
Therefore, following equation is applied to all candidate portfolios obtained by step 1 in order to select the best portfolio by using information ratio \( IR_i \).
\[ IR_i = \mu_i / \sigma_i \] (22)
The most suitable portfolio is selected, which maximize information ratio $IR_i$ for investment.

REFERENCES