Methodology for Adaptive Management of Internal Value Creation Depth in the Tool and Die Industry

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Abstract
The tool and die industry manufactures tools and dies in one-batch mode and thereby enables any series production of goods. In consequence the demand for tools and dies is highly variable as it depends on the launch planning of new series. In conjunction with the current economic climate the key dilemma for the tool and die industry is formed by the requirement of available resources to flexibly supply tools and dies on the one hand and the requirement of maximal capacity utilisation on the other. The proposed methodology presents an approach to continuously cope with this dilemma by adaptively managing the depth of the internal value creation. Target is the development of hierarchically ordered options for each step of the manufacturing process with regard to its internal execution or external sourcing. As a result the methodology presents a practical instrument for the tool and die industry to flexibly react to the variable demands while controlling capacity utilisation.

Keywords
Tool and Die Industry, Value Creation, Capacity Utilisation, Due Date Reliability

1 INTRODUCTION
The tool and die industry is one of the key industries in the manufacturing sector due to its role in the value chain between the product development and the series production of manufacturing goods. The tool and die industry largely contributes to the economic performance of major economies [1, 2, 3, 4]. Nevertheless the tool and die industry faces margin losses as well as increasing competition from Eastern Europe and Asia [5, 6]. Facing this situation, the industry has to develop differentiators to preserve international competitiveness on the global market.

For the purpose of this paper the word tool will be used synonymously for tools as well as dies.

2 SUCCESS FACTORS FOR THE TOOL AND DIE INDUSTRY
Tool making companies are measured by their customers against three key performance indicators: due date reliability, lead time, and quality [7]. Since quality according to defined tolerances is a prerequisite for placing an order due date reliability and lead time are the differentiating indicators for tool making companies against competitors. As a consequence, in order to be able to meet these key performance indicators the entire order processing needs to be efficient and productive [8, 9]. The target of an efficient and productive order processing is operative excellence [5]. While the demands of the customer have to be attended to on an operative level, a sound strategy and a business model are also required to reach sustained success [10]. Strategy and the stringent derivation of a business model specifically for the tool and die industry have been addressed in different works over recent years. FRICKER has proposed a model for stringent strategy in the tool and die industry [11]. FRICK provided eight successful business models for tool making companies [7]. This work specifically focuses on the target of operative excellence. According to SCHUH operative excellence can be mastered by successfully occupying six action fields in the tool and die industry. These are [5]:

- Product Standardisation
- Process Synchronisation
- Value Creation Design
- Sales
- Knowledge Management
- Employee Development

The action fields of operative excellence require tool making companies to apply principles that have been well established in the series production. While that development has shown significant progress with regard to standardisation and synchronisation, value creation design has yet to be appropriately addressed [8, 9, 12]. Value creation design requires the management of value creation depth as well as the aspect of cooperation with other companies. The value creation depth refers to the amount of processes that are required for the manufacturing of a tool. The systematic use of external suppliers to manage the value creation depth for efficient order processing is addressed in this paper.
3 FIELD OF ACTION FOR ADAPTIVE MANAGEMENT OF INTERNAL VALUE CREATION DEPTH

3.1 Value Creation Management as a Measure to Control Capacity Utilisation and Costs

Increased competition due to global availability of tools, dies, and services at premium quality results in the necessity to reduce prices for the customer. This development has experienced massive intensification in recent years. It may be expected that this development will continue to affect the tool and die industry in the foreseeable future [1].

The development of consumer products is performed in periodic cycles. This underlying circumstance leads to an aggregation of orders for tools when the development phase of consumer products has specified product dimensions. On the other hand there are periods of lack of demand for tools while the development cycle has not progressed to a stage where product specifications would allow the manufacturing of tools. The described situation is shown in Figure 1.

The adaptive management of internal value creation depth specifically addresses the subject by systematically supporting the use of internal and external resources to realise the order processing. Given the established characteristic of different types of orders this task is especially demanding. The adaptive character addresses the required flexibility of such a methodology to adapt to the demands of different situations with regard to handling orders and capacities. The trend that can be observed in other industries to focus on certain competencies only has resulted in consistently low levels of value creation depth – this phenomenon however is not identified in the tool and die industry [5]. In series production, in the automotive industry especially, the value creation depth reaches levels below 30% [13]. An increased demand for mastering co-operation with suppliers is a result of this development. In the tool and die industry the value creation depth is at about 70% [14]. The identified potential and gap to series production underscore the demand for a measure to support the management of internal value creation depth in order to become more productive and efficient as operatively excellent tool making companies.

3.2 Analysis of Prior Works on Management of Value Creation Depth

Smith established in 1776 that everyone should focus on the field he is best in [15, 16]. The concept of management of value creation depth can be traced back to Coase who posed the question of what motivates a company to execute one transaction more or less [17, 18]. In current practice the management of value creation depth is directly linked to the subjects of outsourcing and make-or-buy decision making. Outsourcing refers to the permanent use of external sources to complete defined processes [19, 20]. On the other hand make-or-buy is focused on short term decisions that have less strategic character than outsourcing.

Outsourcing literature describes the concept of focusing on core competencies. However a practical approach with regard to the execution in the tool and die industry or other small batch industries specifically could not be identified. Although the approach to make-or-buy is more practical, literature predominantly addresses in which scenarios sourcing is required [21, 22]. With regard to industry focus works on the manufacturing industry in general do exist [23], but small batch industries are not specifically addressed.

This leaves the field of supplier management for analysis, as supplier identification and selection are part of the operative management of value creation depth. However, supplier management is defined as an organising administrative function which is continuously required to enable outsourcing or make-or-buy and does therefore not address the operative aspect of value creation design [24]. Hence it may be established that there is no
practical measure available for the tool and die industry in the literature that supports efficient order processing.

4 METHODOLOGY FOR ADAPTIVE MANAGEMENT OF INTERNAL VALUE CREATION DEPTH IN THE TOOL AND DIE INDUSTRY & CASE STUDY RESULTS

The methodology was developed in collaboration with two partners from the tool and die industry that served as case studies for the practical validation of the theoretical approach. The two industry partners are both internal tool making companies of manufacturing companies, one located in Germany and one located in Switzerland. The tool making company in case A produces injection moulding tools. The tool making company in Case B produces massive forming tools (case B). As the tools and respective production parts of both partners differ vastly in complexity and type of application, it was possible to show that the methodology is flexible enough to be applied in both cases. The methodology aims at incorporating all demands and requirements mentioned to offer a potent instrument for the design of the value creation in the tool and die industry. The methodology consists of three steps which are performed in a defined consecutive order. At the end of each subsection the more specific results and lessons learned from the two case studies are reported.

The methodology is described using the example of a fictive tool making company. Initially one looks at this tool making company that is confronted with the challenge of having to adapt to volatile capacity utilisation. Furthermore the company is unable to entirely satisfy the customer demands with the internal value creation process only. The company has developed and employs a stringent and logical strategy. In addition, a business model is established that has been logically derived from the company’s strategy.

The core competencies as differentiating abilities against competition of the tool making companies have been identified as part of the strategy and business model [25, 26]. The core competencies have to be explicitly strengthened by the methodology to create and shape a competitive edge with the management of value creation depth. Therewith the company possesses a sound set-up with regard to strategy and business model and can approach value creation design as a core part of operative excellence.

4.1 Step 1: Status Quo of Processes and Products

The first step of the methodology serves the purpose of accumulating all data and information required to structure the methodology for a company individually. The aim is to make the data and information available to the user for its usage in the further steps. The data should accurately represent the status quo at the tool making company with regard to the relevant aspects of the value creation depth.

The accumulation of information refers to the employed order processing and the manufactured tool.

For the acquisition of relevant process information the order processing has to be mapped in chronological order [27]. For the tool and die industry, the process is initiated in the engineering department and finalised in the try-out department which is responsible for checking whether parts can be produced to the required specifications. The process mapping can be carried out using illustration techniques such as value stream mapping or similar methods. The desired result is an increased transparency of the entire process structure with the inclusion of all process steps. Subsequently the transparent process structure will serve as input for assessing relevant process steps regarding their value creation depth.

The process steps need to be assigned to so-called configuration modules. A configuration module is the smallest value creation unit of a tool that is manufactured by one autonomous entity – the entity can either be the tool making company itself or an external supplier. Depending on the complexity and interaction of different process steps the size and amount of components of a configuration module may vary. The smallest possible size of a configuration module is one manufacturing process that can be performed independently. The largest possible configuration module on the other hand is an entire order by the customer. In figure 2 the definition process of configuration modules of one tool is displayed. Therewith all parts of a tool are defined that can be considered for manufacturing by different entities.

![Figure 2 - Identification of configuration modules.](image-url)
As the result of step one, all relevant information for the further execution of the methodology have been defined. Order processing has been mapped and all process steps of which it is composed have been detailed. The products have been structured into configuration modules that represent units that can be used to be manufactured by internal or external resources.

Case Study Results
The order processing of both partners were mapped using a tool called “aixperanto”, which was developed to illustrate the chronological order of process steps. This initial step helped to identify the relevant process steps that should be further analysed regarding their value creation depth. The identified process steps (e.g. milling, grinding etc.) were then assigned to the respective configuration modules. At this point, the first differences in the application of the methodology were found. While injection moulding tools can consist of several hundred individual components, massive forming tools usually consist of fewer parts. Therefore the definition configuration modules in the two cases yielded different results. For case A, a configuration module could consist of a single tool component or a certain number of manufacturing steps of a given component. For case B the complete massive forming tool itself was defined as the configuration module. In each case the configuration modules were detailed regarding the relevant process steps. The configuration module definitions were used as input for the next steps of the methodology.

4.2 Step 2: Definition of Determinants for the Management of Internal Value Creation Depth
The determinants for the management of internal value creation depth are the entirety of aspects that can be differentiating with regard to the outcome of a sourcing decision process. Determinants for the management of the value creation depth have either an absolute or a continuous character. Determinants with absolute character may immediately result in a sourcing decision. An example for such a determinant is know-how-protection. If a process is know-how-intensive it has to be executed internally regardless of further circumstances. A continuous determinant does not have an absolute effect on the sourcing decision, but influences the decision based on its value. The total amount of determinants is not limited. For all determinants it has to be specified how the measurement of the determinant has to be conducted. While the measurement system for determinants with absolute character is binary, the measurement for other determinants is performed on a continuous scale.

The validation of the methodology in the case studies underscored the necessity for the measurement to be simple enough to be adequate for day-to-day work. Thus the range of each determinant with continuous character is divided into three parts that represent a positive, neutral and negative value. For the purpose of visualisation those parts are marked with traffic light colours where green represents the positive value. An example for the evaluation system is shown in figure 3.

Any process has to be assessed in a first step with regard to the absolute determinants as this can lead to immediate exclusion from further evaluation. Those determinants are part of the exclusion phase. A process that is still eligible for a flexible sourcing decision reaches the evaluation phase with continuous determinants. The purpose of the evaluation phase is to rank all processes with regard to internal or external execution. To achieve this a value is assigned for each of the three value parts of a determinant. Here a red evaluation of a determinant equals zero points, yellow equals one point and green equals two points. That evaluation refers to the execution of a certain process at a defined internal or external source.

<table>
<thead>
<tr>
<th>Name</th>
<th>Relevance</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Know-how-protection</td>
<td>yes</td>
<td>no</td>
</tr>
<tr>
<td>Machine ownership</td>
<td>yes</td>
<td>no</td>
</tr>
<tr>
<td>...</td>
<td>yes</td>
<td>no</td>
</tr>
</tbody>
</table>

Evaluation phase

<table>
<thead>
<tr>
<th>Name</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Price</td>
<td>Price relative to benchmarking group</td>
</tr>
<tr>
<td></td>
<td>&gt; 10%</td>
</tr>
<tr>
<td></td>
<td>+/- 10%</td>
</tr>
<tr>
<td></td>
<td>&lt; 10%</td>
</tr>
<tr>
<td>Product quality</td>
<td>Share of accepted received orders</td>
</tr>
<tr>
<td></td>
<td>&lt; 70%</td>
</tr>
<tr>
<td></td>
<td>70% ≤ acc. ≤ 90%</td>
</tr>
<tr>
<td></td>
<td>&gt; 90%</td>
</tr>
<tr>
<td>Service</td>
<td>Offer of services</td>
</tr>
<tr>
<td></td>
<td>none</td>
</tr>
<tr>
<td></td>
<td>if requested</td>
</tr>
<tr>
<td></td>
<td>initiatively</td>
</tr>
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<td>...</td>
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Figure 3 - Evaluation system for sourcing decisions.

The score of a process is then calculated with:

\[ p_{ij} = \sum_{k=1}^{n} cd_{ijk} \]  

Where \( p_{ij} \) represents the score of the process \( i \) at the source \( j \). \( Cd \) stands for the value of the continuous determinant \( k \). This assumes equal importance of all continuous determinants for the decision on the source of a certain process. With a weighting system it is possible to refine the relative importance of the continuous determinants by weighting them differently. Then the score of a process is calculated with:

\[ p_{ij} = \sum_{k=1}^{n} cd_{ijk} * w(cd_k) \]  

With \( w \) being the weighting function of the continuous determinant \( k \). The necessity for the employment of a weighting system depends on the
context of application for a specific company and has to be defined individually.

As described above the evaluation system has to be modified for the individual situation in a given company. Additionally the situation of application of the system depends on the point in time in the order processing. As illustrated in figure 4 there are three different possible scenarios for the moment of decision-making. In the planning scenario the order for a tool has not yet been placed. In this scenario the management of the internal value creation depth is part of the overall planning process. Determinants in the evaluation system that are of strategic nature have a relatively high value in this case. The second scenario is executed as part of the detailed planning of the entire manufacturing process of a tool. The exact tool design and its requirements for manufacturing processes are known as well as the available capacity of the defined resources.

\[
p_{ijkl} = \sum_{k=1}^{m} cd_{ijkl} * w(cd_k) \quad (3)
\]

Where \(i\) represents the scenario that the process score is calculated for.

As a result of step two an evaluation system has been set-up to be able to compare scores for processes when executed internally with the scores of execution at external suppliers. The scores specifically account for the strategic goals of the applying company.

Case Study Results

In each case the determinants were derived from the respective tool making company’s overall strategy in order to be able to calibrate the evaluation system along the lines of the individual company’s goals. In case A the most important determinants were “knowledge protection” (absolute) as well as “price” and “lead time” (continuous). In case B the determinants were “availability”, “due date reliability”, and “quality” (continuous). For each continuous determinant specifications were assigned in order to be able to classify the quality of a process at a given entity into a positive, neutral and negative value. For instance, the industry partner of case A considered on-time in less than 90% of the projects as negative, more than 90% as neutral and more than 95% as positive. The evaluation system was then applied to all possible combinations of process steps and internal or external manufacturing resources. In case A 25 separate process steps were evaluated for an average of five possible sourcing entities. The evaluation showed that the quality of the specifications of the determinants was critical and had to be calibrated in several iterative steps to achieve meaningful data. While in case A the evaluation was carried out for the three scenarios “planning”, “detail planning” and “rush order” in case B only one scenario was considered as the planning horizon for this particular industry partner was very short in all situations. The result of step two was a very elaborate spread sheet containing the evaluation scores for all process steps carried out at all relevant internal and external resources.

4.3 Step 3: Determination of Internal Value Creation Depth

After step two the methodology has produced results for sourcing decisions with regard to single processes. However to be able to practically apply the decision to determine the internal value creation depth those results have to be aggregated to the level of configuration modules. Whenever a configuration module consists of more than one process step the sourcing decision may not be clear as each process step of the configuration module may have a different “best source”. In the following the problem of finding the overall best source for a configuration module will be addressed.

The value creation depth for configuration modules has to be calculated for all scenarios separately. For the calculation of a final result all processes of a configuration module need to have an assigned score for their execution at defined sources. \(M\) stands for Make being the internal manufacturing, while \(B\) stands for Buy meaning the external sourcing of a process. The index gives information on the exact source that is preferred for the process (compare figure 5).
As configuration modules have been established as the smallest possible part for which a sourcing decision can be made, one source has to be appointed for the manufacturing of an entire configuration module. The practical validation with the companies showed that there are usually dominant processes which will define the preferred source for all processes required to complete the configuration module. After defining the dominant processes of a configuration module, each one has to be allocated to the resources with regard to the equipment it requires. That is the case for all configuration modules which have not been defined as modules that have to be made internally or externally on a mandatory basis. The application of the scenario is then based on the availability of resources. In situations of capacity peaks where the demand for resources does exceed the capacity that is available at the company a stringent decision for the sourcing of a configuration module can be made. The configuration modules are allocated to the resources. For every configuration module there is a ranking for the entities from which the modules can be sourced. The configuration modules that have to be manufactured internally are listed on top of the diagram and those modules which have to be sourced externally are listed on the bottom. For the externally sourced modules a ranking of available sources is cited. In between all modules are listed that can be made internally or externally, depending on the capacity utilisation in the company. A diagram is valid for one scenario specifically, as the ranking of possible sources differs with the various evaluation systems that have been developed for all scenarios specifically.

**Case Study Results**

In both cases the score for each combination of a configuration module and a source was calculated by adding up the individual scores of each process step that was assigned to a given configuration module. Furthermore, the dominant processes were derived from an analysis of the added value of each individual processes step. The dominant processes then gave an indication of which manufacturing resource a given configuration module should be primarily allocated to. The result of this step was an allocation of configuration modules to each of the partner’s internal resources as well as a ranking of the available sources for the manufacturing of each individual configuration module.

### 4.4 Junction of Steps

The result of the junction of the three established steps is the methodology for the adaptive management of internal value creation depth. The adaptive character of the methodology is defined by the flexibility of attending to different scenarios with regard to the planning horizon. It has been established initially that over time the order volume in a tool making company varies as shown in figure 6. Capacity utilisation defines the amount of configuration modules that are sourced. It has to be evaluated for different types of resources separately as available capacities have to match the manufacturing requirements of the tool components. The separation of steps one and two allows the stringent customisation of the determinants according to the actual need of a company that is derived from the set of information required by the second step. As shown in figure 6 the volume of external manufacturing that is performed is dictated by the order volume and inherent capacity utilisation of the resources. The capacity utilisation and order volume are the defining parameters for the management of the internal value creation depth.

**Figure 5 - Detailed make-or-buy diagram for a specified scenario.**

**Figure 6 - Example for application of the methodology at different points of time.**

The result of the methodology is a guideline on where configuration modules should be sourced in different scenarios. With this methodology the tool and die industry is supplied with a capable tool to design the value creation and increase the level of operative excellence.

### 5 CONCLUSION

The methodology introduced in this paper offers a practical instrument for the operative value creation design of a tool making company. As such it delivers an important contribution to making operative excellence practically accessible for tool making companies.

It was identified that while product standardisation and process synchronisation have been addressed extensively, the remaining action fields of operative
excellence still need to be developed. Sales as well as employee development and knowledge management have yet to be addressed to enable tool making companies to develop towards operational excellence.

In another dimension the capability and knowledge created in a tool making company by this methodology can be employed further. As extensive information about possible suppliers exists in a unified structure after the application of the methodology, that information can be employed further to specifically design the supplier landscape a tool making company uses. The proper execution of the methodology requires the management of suppliers on an advanced level. This aspect has to be addressed scientifically in the future as it represents a further dimension for the value creation design in the tool and die industry.

The determinants of the methodology are customised in accordance with the specific needs of the company applying the methodology. The competencies are not evaluated with regard to their fit with the market and the product portfolio offered by the tool making company. This motivates further works on competence focus of tool making companies.

6 REFERENCES


7 BIOGRAPHY

Günther Schuh received his doctorate degree from the RWTH Aachen University. He was originally appointed Professor at the University of St. Gallen. Günther Schuh currently holds the Chair for Production Engineering of the Laboratory for Machine Tools and Production Engineering (WZL) and is a member of the board of the Laboratory for Machine Tools and Production Engineering (WZL) as well as the Fraunhofer Institute for Production Technology.

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