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Identifying and Structuring Objectives for the Design of Lean Processes in Manufacturing Companies

Approach and Results of an Empirical Survey among Small and Medium-Sized Enterprises

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***Abstract*— This research presents a value-focused thinking approach to identifying and structuring of objectives for the design of value-added production systems for manufacturing companies. The approach combines manufacturing, logistics and lean principles and emphasizes the importance of the decision-maker during the design of a value-added production system. Additionally the importance of the decision-maker is demonstrated through the presentation of the results of a conducted survey among small and medium-sized enterprises.**

***Keywords*— value-added production system, lean production, logistics, production logistics, decision-making, objectives, value-focused thinking, SMEs**

I. Integration of Manufacturing, Logistics and Lean Production

The importance of logistics increases across all industry sectors and sizes of companies. Especially for manufacturing companies it has evolved from its origin role as a functional support, towards a holistic and value-added long-term success factor. [1] Due to the increasing share of logistic activities, involved in the overall value-added production process, an optimization potential of improving efficiency and reducing costs arises especially from the continuous and holistic integration of logistics and manufacturing processes. Research studies show that the continuous integration and optimization of such value-added oriented production systems, also known as production logistics, can reduce the costs of small and medium-sized enterprises (SMEs) up to 25%. [2]

The general importance and the overall advantages of the integration of manufacturing and logistic processes are further reflected by recent surveys among German manufacturing companies. Therefore, 94% of the manufacturing companies recognize the integration of manufacturing and logistics as an efficiency advantage for their production system.

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Figure 1 provides an insight of the study conducted by Miebach Consulting and shows that cross-departmental projects, common process design, strategic planning, common meetings and the implementation of lean principals are starting points to improve collaboration and integration between manufacturing and logistics. [3]

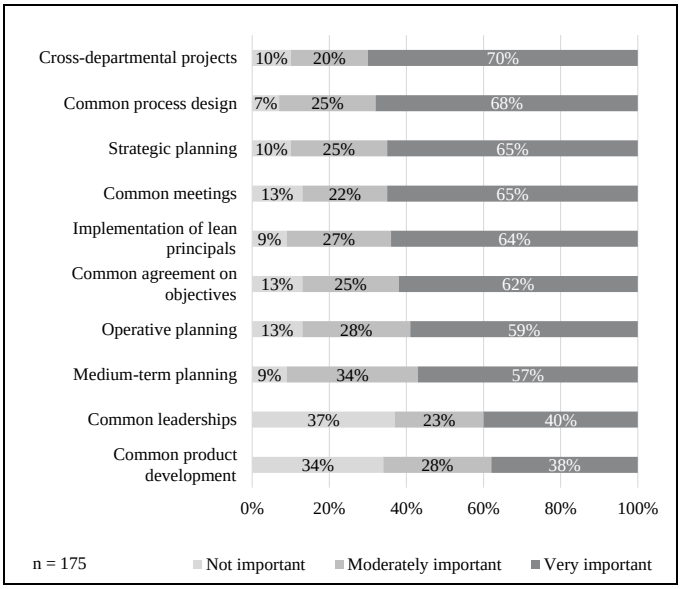

Figure 1. Starting points to improve collaboration between manufacturing and logistics [3]

The increasing integration of manufacturing and logistic processes in production systems leads to the transfer of Lean Production principles to the design of logistic processes and vice versa. This represents a consequential development since both, Lean Production and Lean Logistics, aim to eliminate parts of processes which have no value from a customer point of view, while ensuring that the customer gets the products as quickly as possible. [4, 5] This further development and the adaption of the Lean Production philosophy supports the current market-driven requirements of high performance and low costs. By meeting these requirements, e.g. through integrated and value-added oriented designed production systems, manufacturing companies are able to gain a competitive advantage and effectively optimize their processes. [6, 7]

II. Decision Support, Identifying and Structuring Objectives

A. Decision-Making Process in Small and Medium-Sized Enterprises

To achieve a value-added oriented production it is first of all necessary to analyze the current situation with regards to gain a deeper understanding of the actual state of the production system and its characteristics. Afterwards the decision-maker needs to identify and structure the individual objectives in order to be able to effectively select appropriate lean methods for the production system. The decision-making process itself is iterative and consists of the following generally accepted six steps:

(1) identify problem,

(2) develop decision criteria,

(3) allocate weights to criteria,

(4) develop alternatives,

(5) analyze alternatives and

(6) select an alternative. [8]

The individual and case-dependent application of these steps is the basis for each decision-making process within manufacturing companies. Especially for SMEs this systematic problem-solving approach is difficult because they have limited human resources and missing experience in such methodical holistic approaches to problem-solving. [2]

These arousing difficulties are demonstrated by the insufficient analysis of the current situation, the non-value-oriented identification of actual objectives for an effective design and the disruptive transition between the analysis (steps 1 to 5) and decision (step 6) phase. [9] These circumstances lead to optimization measures, e.g. a particular selection of a lean method to optimize the production system, which do not contribute to the achievement of the decision-maker's aimed objectives. In some cases, this shortfall may even lead to deteriorations within the production systems due to side effects of selected alternatives and insufficient formulation of objectives. [10]

B. Identification of Objectives

For achieving an improvement in view of aimed at objectives, one must first identify the relevant objectives. In this identification process one should not follow generic recommendations, i.e. the suitability of measures should not be schematically and equally evaluated for all companies. Rather, one should carefully examine to what extent a measure meets the objectives of the company concerned. In general, the full identification of objectives is very demanding.

If a person or an organization is asked whether the objectives were fully known, the answer is mostly "yes". However, in an empirical study, Bond, Carlson and Keeney could refute this. [11] In a first step, participants were asked to list as many objectives as possible for a very important decision situation in their life. These situations included such decisions as the choice of an internship, a dissertation topic or the future career.

In a next step, the participants were asked to mark all objectives they judged as relevant for themselves in a master list, which was compiled by experts and contained all relevant objectives. Finally, the participants have assessed the objectives according to their importance. On average, the participants listed about six objectives in the first step and marked about six more in the second step. The participants rated the new and not self-generated objectives as equally important as the objectives they identified in the first step of that experiment. Similar observations were made with the ability of companies to identify objectives.

The "value-focused thinking" approach after Keeney [12] is a possible and effective starting point for a complete identification of objectives. This approach focuses on the values and objectives of decision-makers and examines first of all what they want to achieve in a decision situation. Afterwards, appropriate alternatives will be evaluated in accordance with the aimed at objectives. This "value-focused thinking" approach defines a decision problem via the objectives of the decision-maker and not via the available alternatives to solve the problem ("alternative-focused approach"). [12, 13]

The approach usually starts with the setup of a wish list. As a suitable starting point serve questions to the decision-makers such as "What do you want to accomplish in the given situation?" or "Which values and interrelated objectives do you pursue?". Decision-makers should try to increase the number of values and objectives several times by wider and deeper thinking. The answers provide a list of values and objectives and thereby a basis for a more in-depth search according to other objectives. The discussion with stakeholders can extend one's own, initially restricted, perspective as well. [12]

Furthermore, it is important to formulate objectives clearly. Thereby it is recommended to describe objectives with a noun, a verb and a preferential direction, for example, "minimize error rate", "minimize waiting times" or "increase quality". [13]

C. Structuring of Objectives

After the full identification of objectives, it is helpful to structure them in a reasonable manner. A suitable instrument for structuring is the representation of objectives in a hierarchy with primary and secondary objectives.

Decision theory distinguishes between fundamental objectives and means objectives. Means objectives serve to achieve a higher-level objective. They thus serve as a means to achieve another objective. Fundamental objectives however, are pursued for their own sake. [13, 14] The objective "minimize production time" for instance, doesn't indicate an end itself, but it contributes to "minimize overall production time" which is in turn used to "maximize performance". In

contrast, "maximize performance" is a fundamental objective of a value-added production system.

The classification may differ from each other in various decision-making situations. However, the distinction between fundamental and means objectives is the basis for the structuring of objectives in a means-ends objective network. [15] Measures and their impact on objectives are depicted in a means-end objective network. This serves the purpose of generating meaningful alternatives and can be a first step towards the formulation of a quantitative model of effects. [11, 15]

III. Decision Support for the Design of Lean Processes

A. *Identification of Objectives for the Design of Lean Processes*

The first identification of manufacturing and logistic objectives was carried out on the basis of a broad analysis of existing scientific approaches and collections of objectives applied in the field of the design and analysis of production and logistic systems. Essential components of this analysis were e.g. scientific papers, engineering standards, technical guidance and standard reference works. [16, 17, 18, 19, 20, 21, 22, 23] From this first analysis, a comprehensive list of potential objectives in the field of manufacturing and logistics was derived. The derivation and thus identification of objectives was conducted without the influence of subjective preferences of the decision-makers. Afterwards the "value-focused thinking" approach was used to achieve a complete list of relevant objectives. There are several techniques that can help to stimulate the identification of further objectives. These techniques are shown in Table I.

Based on the desired wish of a "value-added production" the following wishes were derived: "maximize efficiency", "maximize performance", "maximize flexibility", "maximize delivery performance", "minimize costs" and "maximize availability" (an excerpt of the developed master list). By applying the structuring approach (item 9 in Table I) to the objective "maximize availability", the objectives of maximizing personnel, machine, material and information availability were identified. In a next step, the objective "throughput time" was investigated on possible quantification (item 10 in Table I). Therefore, the components known from the production throughput time, e.g. production time or set-up time, were identified.

There are several techniques that can help to identify all possible objectives. This applies particularly to the decision-makers in SMEs, e.g. by trying to identify various objectives starting from a certain initial situation (item 5 in Table I) or by studying the possible consequences of the alternatives (step 4 in Table I). If many objectives are already known, these approaches can help you to identify additional objectives. These techniques contribute to the completion of a system of objectives and thus substantially support the decision.

TABLE I. TECHNIQUES TO USE IN IDENTIFYING OBJECTIVES [24]

1. *A wish list*. What do you want? What do you value? What should you want?
2. *Alternatives*. What is a perfect alternative, a terrible alternative, some reasonable alternative? What is good or bad about each?
3. *Problems and shortcomings*. What is wrong or right with your organization? What needs fixing?
4. *Consequences*. What has occurred that was good or bad? What might occur that you care about?
5. *Goals, constraints, and guidelines*. What are your aspirations? What limitations are placed upon you?
6. *Different perspectives*. What would your competitor or your constituency be concerned about? At some time in the future, what would concern you?
7. *Strategic objectives*. What are your ultimate objectives? What are your values that are absolutely fundamental?
8. *Generic objectives*. What objectives do you have for your customers, your employees, your shareholders, yourself? What environmental, social, economic, or health and safety objectives are important?
9. *Structuring objectives*. Follow means-ends relationships: why is that objective important, how can you achieve it? Use specification: what do you mean by this objective?
10. *Quantifying objectives*. How would you measure an achievement of this objective? Why is objective "A" three times as important as objective "B"?

B. *Structuring of Objectives for the Design of Lean Processes*

After the complete identification of objectives, they must be structured in a system of objectives. In practice the "top-down" and "bottom-up" approaches can be used to classify objectives into fundamental and means objectives. By using the top-down approach, a higher-level objective can be decomposed into lower-level objectives that help to accomplish the higher-level objective. This procedure is repeated until sufficient operational objectives have been achieved. The bottom-up approach on the other hand, begins by asking the question "Why is this accomplishment valuable?" The bottom-up approach to create a system of objectives is a sequential process of broadening one's narrow focus on specific threats, issues, or management prescription to derive higher-level objectives. [12, 13, 14] For the structuring of objectives according to the bottom-up approach, objectives should be subject to the "why is it important" test in order to determine whether it is a fundamental or a means objective. [12] For example, the fundamental objective "maximize efficiency" can be decomposed into the objectives "minimize administrative time", "minimize production time" and "minimize internal material flow time". A part of the system of objectives developed in this way is shown in Figure 2. The developed system of objectives consists of the three fundamental objectives "maximize performance", "minimize costs" and "maximize sustainability". The fundamental objectives are decomposed into several means objectives, which consist of further means objectives through

a multi-level hierarchy. The structure of the system of objectives is generic and universal for all types of manufacturing companies.

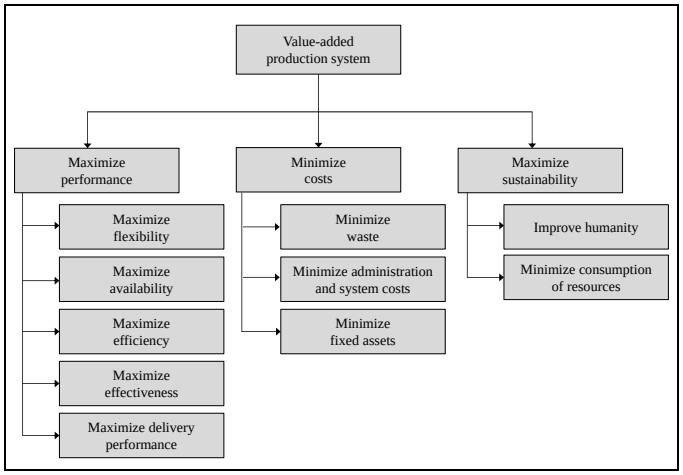

Figure 2. Developed system of objectives for the design of a value-added production system [25]

IV. Empirical Survey Results

A. *Survey Design and Participants*

The following statistics are derived from data of a current survey, carried out by the University of Bayreuth and the Fraunhofer Project Group Process Innovation in 2015. It focused on the decision-making process of German SMEs with a manufacturing background. The survey was directed to the managing directors and chief operating officers of each company. Each of the decision-makers had taken at least one important decision in the past five years, e.g. layout design or quality improvement methods. The decision could be related to any project in the field of the analysis and design of a value-added production system. The entire survey consists of 29 questions concerning the basic structure of the company, current status of the value-added production system and the decision-making process. 101 decision-makers participated in the survey. The number of employees was measured by full-time equivalents and answered by 96 SMEs (see Table II).

TABLE II. PORTION OF EMPLOYEES OF THE PARTICTIPATED COMPANIES

Number of employees	Portion of companies
0 to 9	24.0%
10 to 19	28.1%
20 to 49	19.8%
50 to 99	12.5%
100 to 500	15.6%

Respondents were sampled across 17 industry sectors. Figure 3 shows the distribution of industry sectors. The largest representatives of the survey are construction (17.3%), finishing trade (16.3%) and engineering sector (10.2%).

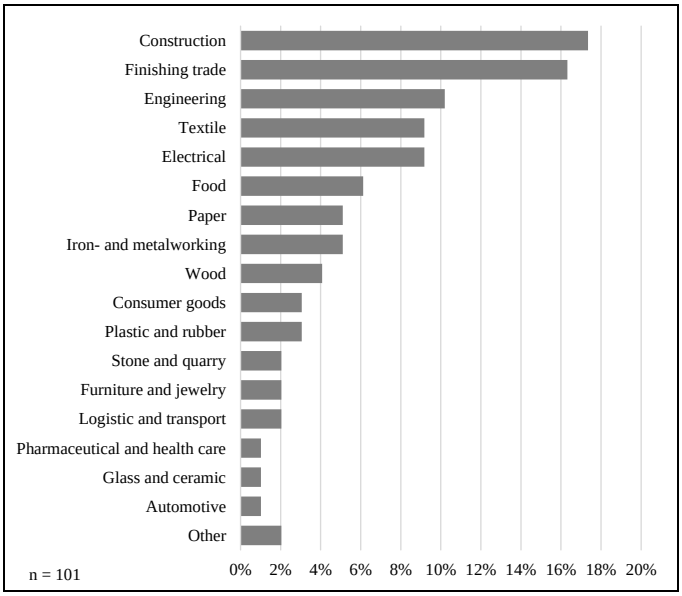

Figure 3. Distribution of industry sectors

On the one hand, the survey is designed to form a comprehensive database for the development of a decision support system. On the other hand, the survey serves the purpose to evaluate the current status of manufacturing companies, their general approach to manufacturing and logistics decisions and their individual capabilities to identify and formulate objectives. In addition to the individual evaluation of each participant's objectives, it is possible to merge the objectives to the developed system of objectives for the design of a value-added production system (see Figure 2).

B. *Survey Results*

In one of the questions, the participants were asked to express up to 16 important objectives of manufacturing and logistics. The process of identifying objectives requires deep production process understanding, significant creativity and hard thinking. On average, each participant could only identify 5.7 objectives. These identified objectives were mostly means objectives and seldom fundamental objectives. The means objectives were aggregated to the corresponding fundamental objective (see Figure 4).

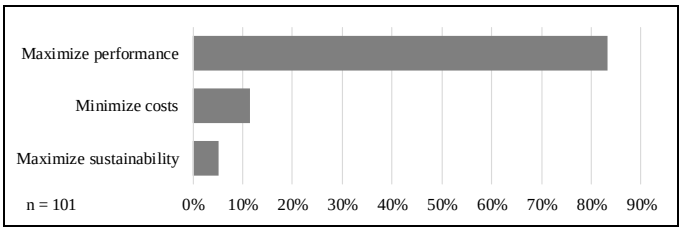

Figure 4. Most frequently expressed fundamental objectives

Figure 5 shows the most frequently expressed means objectives of the associated fundamental objective "maximize performance". The objectives "maximize availability" (9.8%), "maximize delivery performance" (17.2%), "maximize efficiency" (31.4%), "maximize effectiveness" (25.5%) and "maximize flexibility" (16.0%) were expressed.

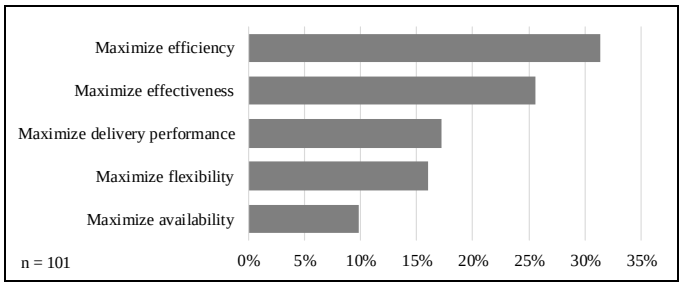

Figure 5. Most frequently expressed means objectives of the fundamental objective "maximize performance"

Beside the individual identification and formulation of objectives, participants were asked to assess the importance of various given means objectives from a predefined master list. These means objectives were subsequently aggregated to one of the three corresponding fundamental objectives. Figure 6 presents the preferences of the fundamental objectives "maximize performance", "minimize costs" and "maximize sustainability".

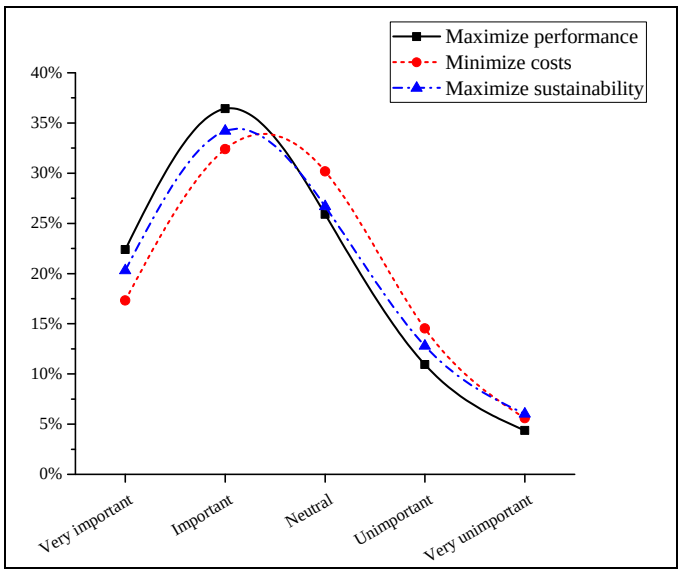

Figure 6. Allocation of preferences of the fundamental objectives for the design of a value-added production system

For 58.8% of the participants it is very important or important to "maximize performance". On the contrary, "maximize sustainability" is more important to the participants than "minimize costs" (54.5% vs. 49.7%). The assessment of preferences revealed that when given a master list, participants prefer the objective "maximize sustainability" over "minimize costs". But in comparison to the capability of identifying and formulating objectives, it becomes apparent that participants formulate on average twice as much costs related objectives than sustainability related ones.

A further assessment of the preferences concerning the fundamental objectives points out that each of the fundamental objectives is almost equally preferred among the participants. However, the expression of individual identified and formulated objectives clearly states that the majority of objectives is performance related (see Figure 4).

Beside the evaluation of the identification, formulation and structuring of objectives it is quite interesting to assess the difficulties in the decision-making process of SMEs. Table III shows that companies especially notice problems because they have limited time resources, insufficient data availability and shortcomings in general experience concerning the decision-making process.

TABLE III. TOP 5 DIFFICULTIES IN THE DECISION-MAKING PROCESS

1.	Limited time resources
2.	Insufficient data availability
3.	Limited experience
4.	Limited human resources
5.	Limited know-how

The assessed difficulties (see Table III), based on the conducted survey, verify the general perception of limited methodical holistic approaches to problem-solving of manufacturing SMEs.

C. Conclusion

The results show that individuals have difficulties to identify all for the decision relevant objectives, when faced with the problem of designing a value-added production system. Using the "value-focused-thinking" approach, more objectives can be identified and be used to improve the decision-making process. The presented system of objectives is based on this approach and includes the integration of manufacturing, logistics and lean principles. Each of the identified means objectives can be measured by standard key performance indicators of manufacturing and logistics.

The analysis of the survey shows, that there is a need to support the decision-makers in SMEs during the process of identifying and structuring objectives in order to effectively design a value-added production system.

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