SZENT ISTVÁN UNIVERSITY

# Advanced production and quality management tools for the Hungarian agricultural machinery manufacturing sector

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## ABBREVIATIONS

| | |
|---|---|
| 5S | Seiri, seiton, seiso, saiketsh shitsuke (Sorting out, arranging, clearing, standardisation, maintenance) |
| BRAINSTORMING | Brainstorming |
| CAD | Computer aided design |
| CAM | Computer aided manufacturing |
| ERP | Enterprise resource planning |
| FMEA | Failed model and effects analysis |
| HEIJUNKA | Balanced production |
| IMSS | International manufacturing system |
| JIT | Just in time |
| KAIZEN | Continuous development |
| KANBAN | Kanban (card, table receipt) |
| LEAN | Lean management |
| ONE PIECE FLOW | One-piece flow |
| PDCA | Plan-Do-Check-Act |
| POKA-YOKE | Poka-yoke (error protection) |
| QFD | Quality Function Deployment |
| SMED | Single minute exchange of die |
| SPC | Statistical Process Control |
| SWOT | Strengths-Weaknesses- Opportunities-Threats |
| TPM | Total Productive Maintenance |
| VSM | Value Stream Mapping |

# 1. INTRODUCTION, OBJECTIVES

## 1.1. The significance and timeliness of the selected topic

In the 21st century, efficiency in industrial production is also of great importance, as in the intense competition only the organization effectively capable of producing modern products and producing quality products and services can survive and succeed in the long term. Nowadays, customer needs are intensifying and changing rapidly, so it is necessary to focus on the process view, the quality associated with the right price, the speed and the flexibility. In this intensified competitive environment, the importance of production and quality management in the management areas is emphasized. Using the toolbox of these areas, the losses can be explored, eliminated or prevented during the production process, but the application of the tools used and associated approaches is not a goal but a means of increasing the efficiency and competitiveness of the company.

The Ministry of National Economy showed in 2014 that small and medium-sized enterprises (SMEs) represent 99,8% of enterprises in Hungary, thus providing employment to 69,8% of the employed. Moreover, it also plays an economic role with 53,5% of value added. Nowadays, half of the medium-sized companies carry out production activities. Consequently, I consider it important to study modern production and quality management tools for manufacturers of Hungarian agricultural machines typically operating in SMEs. Most of them are located in the countryside, thus they play a great role in retaining and expanding jobs and improving the situation of the Hungarian countryside.

The primary objective of my research is to empirically investigate the extent to which lean production and quality management and production technology tools are used for Hungarian agricultural machinery manufacturers, which should be further emphasized in order to maintain and increase efficiency and competitiveness. Depending on what kind of effects they have on each other, the management areas are placed at the centre of my research together with their joint impact on the supplier's competitive criteria. This will help explore the areas where additional benefits of further development can be gained in the private sector. In this way, it facilitates the development of a product manufacturing process concept that is capable of flexibly producing the capacity of manufacturers to meet instantaneous needs by reacting as quickly as possible.

The presence of a strong and modern agricultural machinery industry is vital to Hungarian agriculture, which can flexibly cover the mechanization needs of small and large companies of Hungarian agriculture and is not afraid to set the goal of breaking into the international market, either. My research would like to contribute somehow to this efficient production process by looking for the exploration of the potentials of processes that are currently hidden in the Hungarian agricultural machinery industry. By mapping them, I can provide practically useful information to professionals who can benefit from product improvement and development processes.

## 1.2. Objectives

During my research work, I have the purpose of revealing the threefold effect of production, quality and lean management. Treating the three management areas together, the impact they have on the production processes in the agricultural industry is measured. It is not my intention to create a model of general validity, which takes into account every small detail of the production process, since the totality of factors that can be taken into account would go beyond the scope of this paper.

The planned research work therefore sets the following main goals:

- I examine the spread of modern production and quality management tools for domestic agricultural machinery manufacturers.
- I explore in the case of the agricultural machine manufacturer that the size of the company has an impact on the extent of the use of quality and lean management techniques and technology tools.
- I demonstrate that the extent of the use of lean management tools has an impact on the level of development of production.
- I identify the strategic directions of quality and lean management strategy and production structure among domestic agricultural machinery manufacturers.
- With my examinations, I demonstrate how the intra-corporate use of lean management impacts the importance of supplier selection parameters.

# 2. MATERIAL AND METHODS

In this chapter, the concept is presented, with the help of which research goals can be set up until the results are presented.

## 2.1. The methodological approach of the research

Following the elaboration of the research objectives and the review of the literature I will focus on the following hypotheses:

Hypothesis 1
At least 50 percent of the tested lean, quality and production management tools are used by manufacturers at a moderate level.

Hypothesis 2
The degree of application of quality, lean management and technological tools increases with the size of the company in the case of the investigated agricultural machinery manufacturers.

Hypothesis 3
Among the agricultural machine manufacturers employing state-of-the-art production and quality management tools, the presence of lean management increases the development of production.

Hypothesis 4
In the case of the investigated Hungarian agricultural machinery manufacturers, strategic and directional strategies are important in quality and lean management strategy and production structure.

Hypothesis 5
The level of employing lean management techniques is influenced by the importance of the selection criteria of suppliers in lean management techniques among agricultural machine manufacturing companies.

## 2.2. Methods of the empirical research

The dissertation relies on primary research to answer the question of the dissertation and examine the hypotheses. The methodology used is the questionnaire survey and the exploratory interview. The quantitative element of the study produces quantified results, which allows the results of the dissertation to be compared with the lessons learned from other research. A qualitative interview gives depth to the results, extends the boundaries of interpretation and potentially it gives an insight into the dimensions of the topic that is related to the subject, but necessarily limited in extent to the formalized structure of the questionnaire.

### *2.2.1. Testing corncob adapter manufacturers*

Primary I research was first conducted in the Hungarian corn harvesting adapters industry. I have investigated three manufacturers in the industry, covering the full range of manufacturers of corncob breakers in Hungary. Within the industry I have examined individual, serial and mass production companies.

From the quantitative and qualitative researches of producers of corn harvester adapters, I concluded that although quantitative data are qualitatively adequate, data are not quantitatively compliant with the SPSS statistical program due to the small number of completed questionnaires (11), so it is necessary to redefine the research sample. In addition to modifying the basic population, it is necessary to revise the questionnaire used in the quantitative research of corn harvesting adapters manufacturers. After the development, it became possible to run an extended questionnaire study of Hungarian agricultural machinery manufacturers.

### *2.2.2. Examination of the Hungarian agricultural machinery manufacturers*

The population of the qualitative research was expanded to the Hungarian agricultural machine manufacturers based on the conclusions of the primary I. research (primary II research). Based on the conclusions, a definitive change is reflected in the quality and quantity of questions.

In Hungary, the production of agricultural machines and / or components and parts is carried out by 140 companies. The majority of these companies are not major agricultural manufacturers. According to the TEÁOR classification, there are currently 64 agricultural machinery manufacturers in Hungary. Since reaching the entire population was practically impracticable, the members invited to the research were the members of the National Association of Agricultural Machine Manufacturers (MEGOSZ) by random sampling.

There is no clear and accurate data on the size of the basic population in the literature, so I calculated N=64 on the basis of the TEÁOR numbers. The accuracy of the total sample at the specified 95 percent confidence is ± 7,8 percent. Regarding the composition of the respondents, I was able to contact the 80% of the Managing Director of the companies I was looking for. The remaining 20 percent was split between production managers and quality management professionals. Such a composition of the respondents proved to be favourable, because everyone invited to the research was well informed and able to fill in the questionnaire statistically.

The questionnaire used in the primary research of agricultural machinery manufacturers was based on questions from the International Manufacturing Strategy Survey (IMSS). Summarizing the development of the questionnaire, 51,55% of the questions remained in the original state of the International Manufacturing Strategy Survey questionnaire. The questionnaire thus created includes about 151 questions in eight thematic groups.

## 2.3. Evaluation of the results of the empirical study

The purpose of the analysis is to accept or reject the hypotheses formulated in the dissertation with statistically significant force.

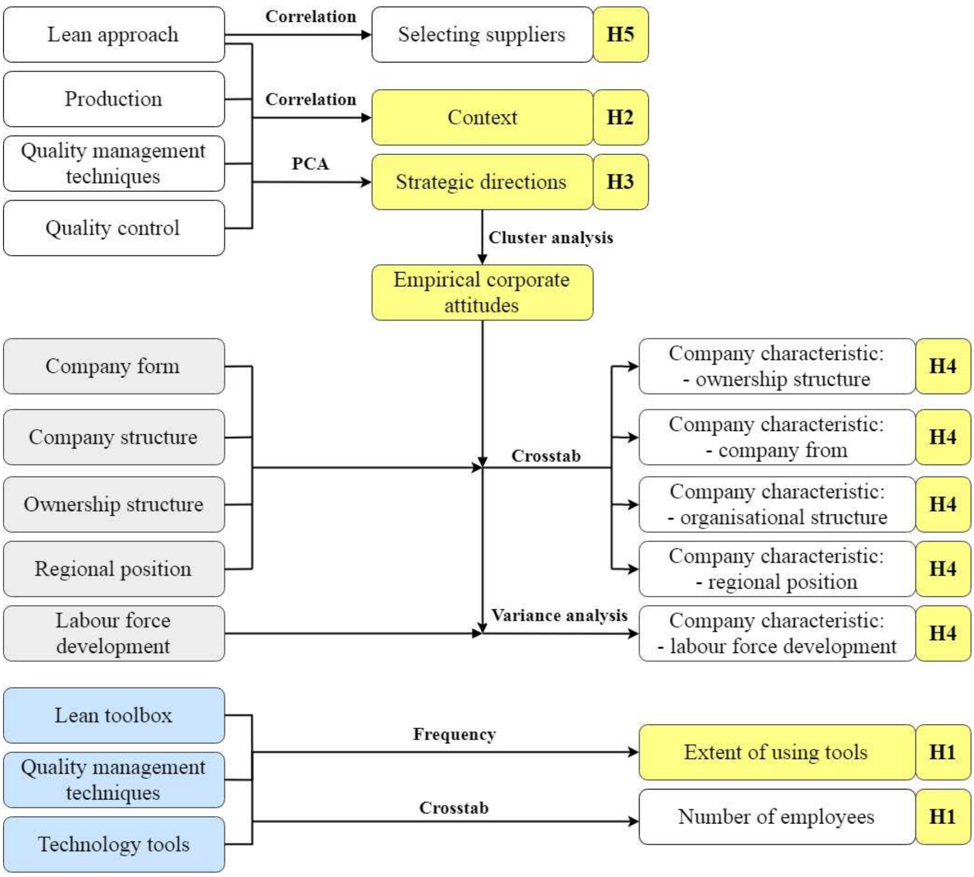


Fig. 1 Testing hypotheses

The first step in the analysis is to group, process and interpret the questions of the questionnaire according to the topics of the hypotheses. Depending on the data content of the research questions, I summarize the variables either in aggregate format, or by means of main component analysis to prepare the further processing of the data.

The second phase of the analysis is to group the questions thematically into group after compressing the questionnaire as described above and to add new dimensions to the new variables in order to reveal the inner contexts of the thematic groups.

In exploring the relationship between dimension reduction variables and thematic groups, Fig. 1 will help to illustrate the statistical methodologies used in the variables. I would like to accept or reject the hypotheses while responding to these research goals.

As a summary, it can be said that with the help of the model illustrated in Fig. 1, I find significant links at Hungarian agricultural machinery manufacturers in the use of state-of-the-art production and quality management tools.

*Statistical methodology*

Several statistical methods were used for my analyses. The starting point of the statistical analysis is the one-dimensional analysis of the variables, which included statistical basic operations (mean, standard deviation, distribution, skewness, slope, mean value, etc.). Their purpose was not to obtain information directly available to the dissertation but to test the conditions for deeper deployment of multivariate analysis (aggregation, correlation analysis, main component analysis, cluster analysis, variance analysis) and the internal structure of the database.

Several tests have been carried out for each of the procedures, but the most professionally explained and statistically relevant results are described in the presentation of each research results. When using the SPSS program package, it is necessary to mention that it can execute any grammatically correct instructions, and therefore, when selecting a particular procedure or modelling and interpreting it, there are significant errors and interpretation limits.

# 3. RESULTS

In this chapter, I present the characterization of research patterns, the dimension reduction process and results, and the formation of thematic groups as well as the exploration of relationships between them.

## 3.1. Characteristics of the empirically tested sample

Before analysing the data in the questionnaire in detail, it is important to describe the results of the sample characteristics. A small proportion of agricultural machinery manufacturers produce between 60% and 70% of the turnover, the obtained results are not proportional to the sales revenue in the sample, but the number of manufacturers. The number of main agricultural machine manufacturers in Hungary can be 64. The sample I examined was 59 agricultural machinery manufacturers, or 92% of the basic population in the focus of the research. I find the research sample favourable for achieving the research goals because my expectations are met, as it comes to the form of the company, the organizational structure, the region and the number of employees.

## 3.2. Applying quality, lean and production management tools

### *3.2.1. Results of dimension reduction*

Lean toolbox

The 8.2. question of the questionnaire examined the use of lean management tools among respondents. I processed the question in aggregate form. Lean management toolbox serves to eliminate losses, and indirectly has an impact on saving costs, investing capital and increasing revenue.

Summing up the mean and averages over the mean (Fig. 2), I divided the techniques into two distinct parts of lean management tools. I considered 50% as the standard based om Hypothesis 1. Techniques that resulted in medium or better typical values for the examined companies include 5S (79,70%), the warehouse equipment (76,30%), the standardized work (64,40%) and the rate of time use (50,80%). It can be said that only 23,52% of the lean management techniques that I have studied are typical of Hungarian agricultural machinery manufacturers. Based on this, lean tools, typically not used by most companies, justified the opposite of what was stated in the lean management tools part of Hypothesis 1.

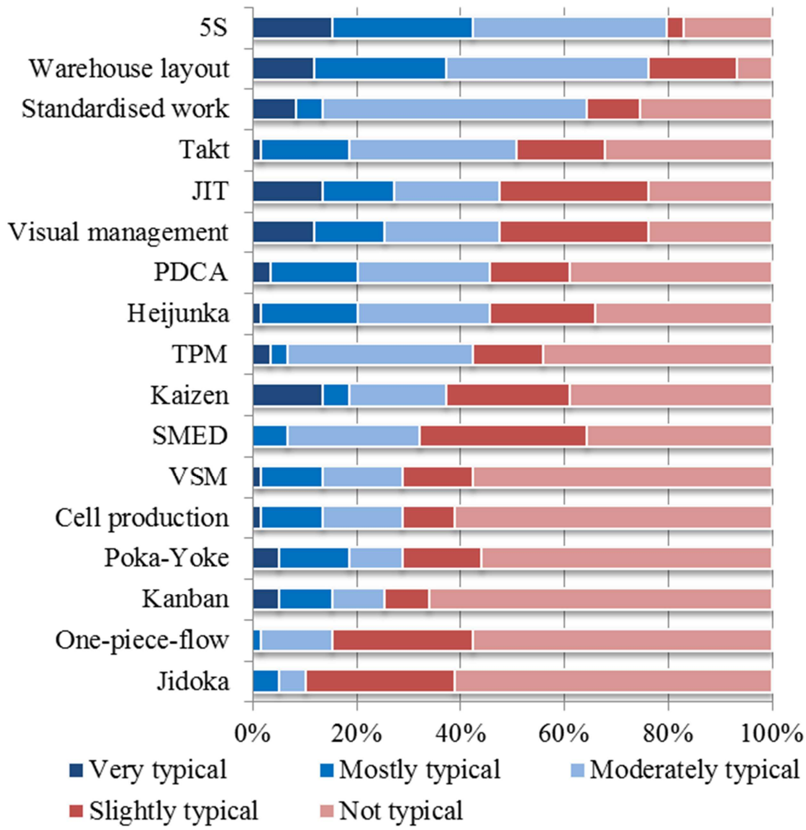


Fig. 2 The frequency of applying lean tools (n=59)

In the following I will analyse whether the number of employees will affect the use of lean techniques.

Table 1. The relationship between the number of employees and the average use of lean techniques

| **Number of employees (person)** | **Average use of lean techniques (%)** | | | | **Total %** |
|---|---|---|---|---|---|
| | **Not typical** | **Slightly** | **Moderately** | **Typical** | |
| Micro (1-9) | 5 | 10 | 7 | 0 | ***22*** |
| Small (10-49) | 5 | 27 | 0 | 2 | ***34*** |
| Medium sized (50-249) | 0 | 20 | 5 | 12 | ***37*** |
| Large (above 250) | 0 | 3 | 0 | 3 | ***7*** |
| ***Total (%)*** | ***10*** | ***61*** | ***12*** | ***17*** | ***100*** |
| ***n (item)*** | | | | | ***59*** |
| ***Significance*** | | | | | ***0,013*** |
| ***Kendall's tau*** | | | | | ***0,279*** |

In this case, I used lean tools to average calculations per company, which resulted in groups based on the average use of lean techniques. On the basis of the cross-table analysis (Table 1), it can be concluded that a weak correlation (p = 0,013, Kendall tau's = 0,279) is found between the size of the company and the extent of the use of lean techniques, so the number of employees in the company significantly determines the use of the methods, so I consider part of Hypothesis 2 on the use of lean management techniques as justified.

Quality Management Techniques

The questionnaire asked about 20 different quality management techniques. The use of quality management techniques independently is not unimaginable either. The results also reflected this pattern so there was no latent relationship between the options. Accordingly, I compiled the answers into an aggregate variable.

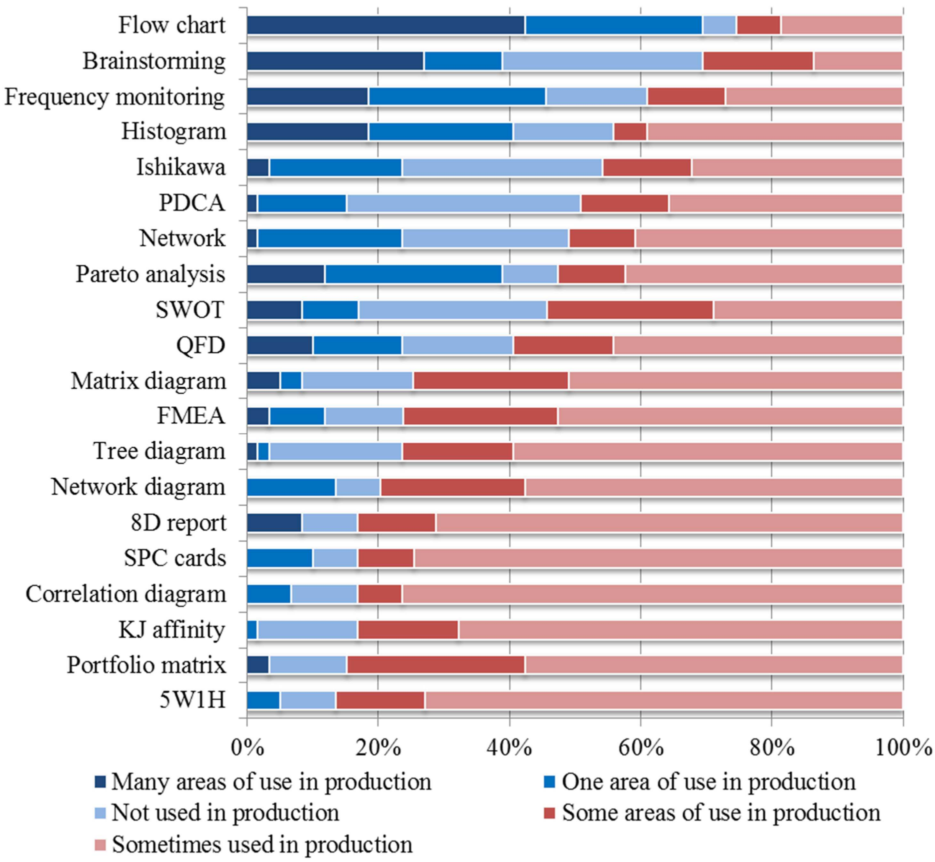


Fig. 3 Frequency of use of quality management techniques (n=59)

Summarizing the averages and averages above the mean (Fig. 3) of the frequency of the use of quality management techniques shows that only 25% of the techniques are used more than 50%. According to the frequency of use in the manufacturing process, the flowchart technique most used by manufacturers (74,60%). More than 50% use brainstorming (69,50%), frequency detection (61.00%), histogram (55,90%), Ishikawa (54,20%), and PDCA (50,90 %). Based on this I rejected Hypothesis 1, which examined the use of quality management techniques.

In the following, I analyse the impact of the number of employees on the extent of the use of quality management tools (Table 2). I averaged the use of quality management techniques and considered it as a dependent variable for each company. It has been concluded that no significant relationship can be detected by examining the average use of quality management techniques with the change in the number of employees among Hungarian agricultural machinery manufacturers. Therefore, I do not consider that part of Hypothesis 2 on quality management techniques to be justified.

Table 2. Relationship between the number of employees and the average use of quality management tools

| **Number of employees (person)** | **Average use of quality management tools (%)** | | | | **Total (%)** |
|---|---|---|---|---|---|
| | **Not used in manufac-turing** | **Sometimes used in manufac-turing** | **Used in one part of manufac-turing** | **Used in certain parts of manufac-turing** | |
| Micro (1-9) | 5 | 8 | 8 | 0 | ***22*** |
| Small (10-49) | 5 | 25 | 3 | 0 | ***34*** |
| Medium sized (50-249) | 3 | 20 | 12 | 2 | ***37*** |
| Large (above 250) | 0 | 3 | 3 | 0 | ***7*** |
| ***Total (%)*** | ***14*** | ***58*** | ***27*** | ***2*** | ***10*** |
| ***n (item)*** | | | | | ***59*** |
| ***Significance*** | | | | | ***0,217*** |
| ***Kendall tau*** | | | | | ***0,155*** |

Technological tools

Like lean's toolbox, respondents were given the opportunity to gain insight into what technology tools they use. Among the answers, there was no latent relationship between the eight options, so I used aggregation.

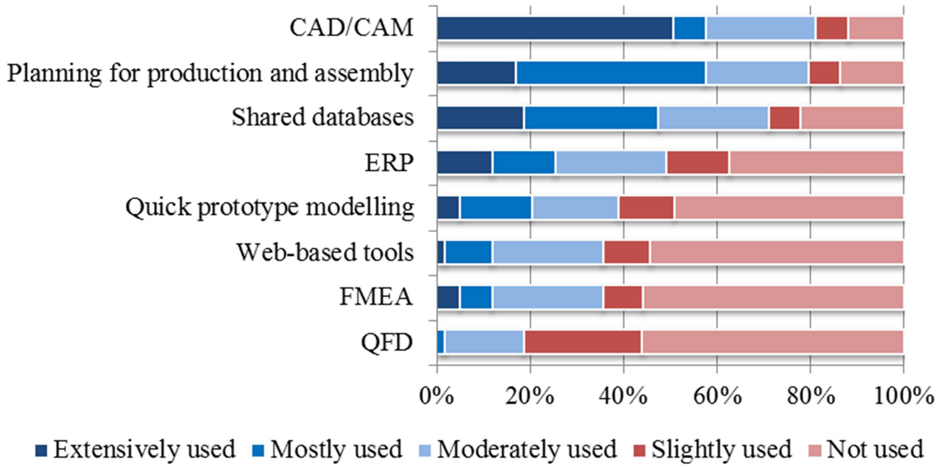


Fig. 4 Frequency of use of technology tools (n=59)

Analysing the frequency of using CAD / CAM (Fig. 4), it can be seen that the majority use it with an extent of 50,80%. 40,70% of the respondents use it for production and planning. Shared databases are used by more people (18,60%) in manufacturing than production planning, but when distribution is further analysed, fewer respondents use it moderately in production (23.70%) than most (28,80%).

After summarizing the frequencies used over medium to medium, Fig. 4 shows that CAD/CAM (81,30%), production assembling planning (79,60%), and shared databases (71,10%) are those that result in more than 50% usage. To sum up, 37,50% (three) of the eight techniques I have examined are frequently used by manufacturers. Based on this, the opposite of Hypothesis 1, which examines the use of technological tools, was justified.

I examined the use of technology tools by number of employees (Table 3). Four groups emerged in the sample, depending on the extent to which companies use technology tools on average. From the data it can be seen that technological tools are used more widely with the increase in the number of employees, so there is a significant correlation of positive medium strength, so the part of Hypothesis 2 on the application of technological tools is considered justified.

Table 3. Relationship between the number of employees and the average use of technological tools

| **Number of employees (person)** | **Average use of technological tools (%)** | | | | **Total (%)** |
|---|---|---|---|---|---|
| | **Not typical** | **Slightly typical** | **Moderately typical** | **Typical** | |
| Micro (1-9) | 10 | 3 | 3 | 5 | ***22*** |
| Small (10-49) | 2 | 25 | 7 | 0 | ***34*** |
| Medium sized (50-249) | 2 | 8 | 15 | 12 | ***37*** |
| Large (250) | 0 | 0 | 3 | 3 | ***7*** |
| ***Total (%)*** | ***14*** | ***37*** | ***29*** | ***20*** | ***100*** |
| ***n (item)*** | | | | | ***59*** |
| ***Significance*** | | | | | ***0,000*** |
| ***Kendall tau*** | | | | | ***0,422*** |

### *3.2.2. Thematic grouping*

The second step of the analysis is to group and interpret elements of a data field generated after the dimension reduction of the questionnaire. Similarly, to the first step, my main instrument was the main component analysis at this stage.

Topic of lean management

The objective of the lean management toolbox in manufacturing and the depth of lean thinking within the company is clearly related to the lean management issue, so I considered their aggregation and the identification of the main motifs a task. The PCA method proved to be successful, as demonstrated by the 0,537 value of the Kaiser-Meyer-Olkin test (p=0,000). The statistical method was able to adequately represent all the variables, and the three main components created retained 75,5% of the original six variable variance. The components that were created could be well interpreted.

The lean management theme consists of three main components. The first component was called "*internal flexibility*". It includes the following variables resulting from the dimension reduction: "lean goal: increase predictability", "lean tools in manufacturing" and lean thinking "organizational approach". Among the Lean Thinking variables, the "Integrated Approach" and the Lean Objectives "Accuracy Increasing" are included in "Eliminating Defects”, the second main component of Lean Management. The third component, the Lean Objective, contains system integrity features, so I named it as a "*system integrity*" from the perspective of lean management.

Topic of production

After the first step of the analysis, I could replace the much larger number of production-related original dimensions with 12 variables. Repeated PCA has now reduced the number of variables to five, all of which have rich information content. The main component analysis kept 74,90% of the variance of the original variables so that I did not have to omit any variables based on the communality values. The KMO test confirmed the feasibility of the analysis (KMO=0,602; p=0,000).

After the main component of the production topic was examined, five components could be clearly distinguished. The first component consists of five variables "operational improvements", "technology enhancements", "internal flexibility", "product and manufacturing planning systems", and "scheduled" maintenance models. Based on these, production was named "*Production: Advanced*". The second factor is named *"Production: Reactive*", which includes "custom production" and "remedial maintenance". In the case of the third component ("*Production: outsourcing"*), the following elements of the dimension reduction have been included in the component: dealing with demand fluctuation through "co-operation", "product development" and "losses due to inappropriate organization of processes". Fourth of the components were named "*Production: losses due to defects*". The last component was termed as "*Production: low resource utilization*".

Topic of Quality Control

Further reductions in the quality control methods applied by the companies are not statistically feasible because they are significant, so in the third step of the analysis I have calculated with the variables that were discovered in the previous step.

## 3.3. The relationship between quality, lean management and production structure

### *3.3.1. The relationship between management areas and the production structure*

I summarize the multidisciplinary assessment of the quality and lean management strategy and the relationships of the production structure in this chapter. The correlation between the processing, the thematic grouping and the dimension reduction of the questionnaire was examined by correlation analysis. Examining the variables after the dimensional reduction, there are several links regarding correlation. There is a strong positive correlation between lean usage: internal flexibility and production: advanced dimension (r = 0,769).

Based on my researches, among the Hungarian agricultural machine manufacturers, analysing the internal contexts of the produced production, lean and quality topics, among the thematic variables there are strong and medium positive and negative correlations that are at 99% significance level. Hypothesis 3, according to which the presence of lean management is growing with the development of production is to be considered justified.

### *3.3.2. Management areas and directions of production structure*

I approached the strategic directions of quality and lean management and production structure with main component analysis. At this level I have compared the three thematic categories analysed to identify the main trends of the strategic direction. After successful analysis, five very identifiable main components emerged, which retained 69% of the variance of the variable input variables and returned at least 50% of variables of each variable.

The five main strike lines are in the following picture (Table 4). The element with the highest weight on the first component is about advanced production (0,928). With high weight (0,875) there is the component that indicates the internal elasticity of lean use. In addition, the sampling quality control (0,651) and the use of the quality management toolbox (0,619) are of high importance. Based on the above, I interpret the first component as an "*advanced*" attitude.

In the next component I did not find a characteristic element. However, the weight of the system integrity (0,663) component of the thematic elements of outsourcing (0,713) and lean management is relatively high. The element with a lower but still significant factor weight (0,510) is the component of the quality control audit. The factor weight (-0,428) of the quality control after the operations has a negative sign, so they are inversely related. That is, according to the manufacturers in the sample, post-operation quality control is not so important. The component thus became the "*coordinating*" attitude.

The third component was called the "*neglecting*" attitude. Here is the weight factor of negative errors (-0,804), which means that the opposite is true.

Table 4. Rotated main component matrix based on lean and quality management and production structure templates

| | Components | | | | |
|---|---|---|---|---|---|
| | **1** | **2** | **3** | **4** | **5** |
| Production: advanced | ***0,928*** | 0,044 | -0029 | -0,010 | 0,014 |
| Use of lean: internal flexibility | ***0,875*** | 0,130 | 0,009 | 0,193 | 0,034 |
| Quality assurance: sampling | ***0,651*** | -0,245 | -0,377 | -0,230 | 0,170 |
| Use of quality management toolbox | ***0,619*** | -0,062 | 0,357 | 0,482 | -0,177 |
| Production: outsourcing | 0,006 | ***0,713*** | -0,204 | -0,018 | -0,073 |
| Use of lean: system integrity | -0,099 | ***0,663*** | 0,390 | -0,109 | 0,017 |
| Quality control: incoming control | 0,398 | ***0,510*** | 0,249 | -0,128 | -0,102 |
| Quality control: after operations | 0,078 | ***-0,428*** | 0,398 | -0,385 | -0,537 |
| Production: losses due to defects | 0,006 | -0,067 | ***-0,804*** | 0,048 | -0,080 |
| Production: low resource utilisation | -0,035 | -0,097 | -0,132 | ***0,817*** | 0,120 |
| Quality control: thorough | 0,447 | -0,078 | 0,139 | ***0,532*** | -0,113 |
| Production: reacting | 0,033 | -0,046 | 0,028 | -0,072 | ***0,803*** |
| Use of lean: eliminating errors | 0,021 | -0,363 | 0,479 | 0,210 | ***0,635*** |
| *Variance* | *22,793%* | *14,072%* | *12,248%* | *10,904%* | *9,090%* |
| ***Interpreting component:*** | ***Attitude: developed*** | ***Attitude: coordinating*** | ***Attitude: neglecting*** | ***Attitude: evolu-tionary*** | ***Attitude: reactive*** |

In the fourth component, there is again a high factor element, the element seeking to make better use of resources from the reduction of the production thematic dimension (0,817). Furthermore, the content of the wide quality control element is associated with a lower weight (0,532). The essence of these components is to use the opportunity within the company to exploit the role of the research model. On this basis, the component is called the '*evolutionary*' attitude.

The last component is also dominated by an element. The highest factor weight is associated with responsive production (0,803). This variable is based on production topics, on order production and on remedial maintenance. The statement with a factor weight of 0,635 here refers to the use of lean management, even to eliminate errors. Based on these findings, the component was named "*reactive*" attitude.

The first component explains 22,793, the second 14,072, the third 12,248, the fourth, 10,94 percent, and the fifth the 9,090 percent of the variance. Based on the third component of the main component analysis (Table 4), the assumption of Hypothesis 4 according to which the typical strategic directions can be defined in the quality and lean management strategy and in the production structure, can be considered justified.

### 3.4. Lean management impact on supply chain criteria

Below I look at the relationship between lean management and the supply chain. I combine the main components of the lean management application with the selection parameters for suppliers, as shown in Table 5. Finding correlations is carried out by correlation analysis. Analysing the correlation coefficients, it can be concluded that there is a correlation between the choice of suppliers and the lean use, at a level of at least 95% significance.

Table 5. Correlation analysis between lean management and supplier selection parameters

| **Dimension reduction variables** | | **Selecting suppliers** | |
|---|---|---|---|
| | | **Ability to integrity** | **Direct benefits** |
| **Use of lean** | **Internal flexibility** | ***0,475**** | -0,001 |
| | **Eliminating errors** | ***-0,309**** | ***-0,282**** |
| | **System integrity** | -0,002 | -0,070 |

$^{*}p<0,05$; $^{**}p<0,01$

Internal flexibility (lean management) and integration (supplier selection) indicate a moderately strong positive relationship (r = 0,475), i.e. the more present the company's operation lean management is the internal flexibility, the more important the criteria of ability to integrity is from the supplier's selection side.

The integration (supplier selection) and the elimination of errors (lean management) show a moderate negative correlation (r = -0,309). That is, the greater the need to eliminate errors from lean management, the lower the degree of integration of suppliers.

Table 5 also shows that there is a significant relationship between direct benefits (supplier selection) and error elimination (lean use) (r = -0,282). This relationship shows a weak negative correlation, so the smaller the need to eliminate the errors with a lean management focus, the more favourable the direct benefits (delivery performance and price) of the supplier's selection parameters.

Practice has revealed that two main components of lean management application can be linked to supplier approaches at least 95% reliability (Table 5). Thus, Lean Management's intra-corporate use has external effects on the supply chain's competitive criteria. Based on this, I consider the 5th hypothesis justified by the statistical results.

# 4. NEW SCIENTIFIC RESULTS

*1. Applying modern production and quality management tools*

Based on the data of the empirical research on the application of quality, lean and technology tools, by cumulating the frequency of moderate, mostly and very typical responses, I have revealed that the investigated agricultural machine manufacturers typically do not employ 75percent of the quality management techniques in the research, 77 percent of lean management toolbox, and 63 percent of the production technology tools.

2. *Applying management techniques relative to the size of the company*

With the survey and frequency analysis carried out with domestic agricultural machinery manufacturers, I demonstrated that among the applied management techniques, those using the techniques, the lean management techniques and the applications of the technology tools show a 95% significance level of positive relationship with increasing the size of the company.

*3. Lean management relationship with the production structure*

By means of empirical studies with agricultural machinery manufacturers using lean management techniques and technological tools as well as statistical methods, I proved that at 99 percent significance level there is a positive relationship between lean management and advanced production for internal flexibility, i.e. with the increase of the lean management direction for internal flexibility, the presence of advanced production is also increasing.

*4. Attitudes to quality, lean management and production structure*

With the survey and main component analysis of the Hungarian agricultural machinery manufacturers, I defined empirical corporate attitudes, which are advanced, coordinating, neglecting, evolving and reactive, using quality and lean management techniques as well as technology tools. The identified attitudes preserved 69 percent of the input variables, so they were able to determine which differences could be detected based on the company's characteristics.

*5. Lean management relationship with the supply chain's competitive criteria*

With the empirical research and correlation analysis conducted among Hungarian agricultural machinery manufacturers, I have shown that lean management, used at lean management techniques at a 99 percent significance level, and the lean management used for internal flexibility, shows a positive relationship with the importance of integration within the supplier selection criteria, i.e. with the intensity of lean management for internal flexibility, the importance of integration among the suppliers' selection criteria increases.

# 5. CONCLUSIONS AND RECOMMENDATIONS

The timeliness of my research is significant, as productivity, efficiency, effectiveness and competitiveness are a constant issue in the life of companies, where the production, quality and lean management areas that I have examined have an impact separately and jointly.

From my surveys, it is clear that quality management techniques are used by manufacturers rather than process development tools to improve the manufacturing process. I suggest that the use of process development quality management tools be given the same attention as techniques for managing inadequacy in the manufacturing process, as these tools can prevent the quality problems that arise in the production process to customers.

My results show that manufacturers typically see their productivity closely related to production-related goals, while only partially exploited opportunities are explored during time-efficiency targets. I propose to focus more on time efficiency on the corporate side so that during the production process one can reach greater use of lean management tools in line with the farm size. In this way, companies could maintain or increase their competitive position in agricultural machine manufacturing. Based on my results, I make the following suggestions for the use of different tools depending on the company size. For large companies, more emphasis should be placed on 5S, TPM, SMED, poka yoke, cell production, single flow, value stream analysis, kanban and jidoka techniques. For medium-sized companies, focus on TPM, cell production, one-piece flow, value stream analysis, 5S and poka yoke. It is important to focus on cell production, value stream analysis, 5S, Kaizen, visual management and jidoca in small companies. For micro-enterprises, Kaizen, standardized work and visual management would be advisable if a greater emphasis than now were placed.

My research revealed that manufacturers are less interested in technological development, as modern technology tools are considerably less emphasized on the basis of survey results than traditional tools. I propose a greater use of modern equipment to achieve customer satisfaction and a more favourable market position.

# 6. SUMMARY

As a first step of my research work, I thoroughly reviewed both national and international literature related to the topic. I focused on the development of three management fields: production, quality and lean management, and their connection to production, the interpretation of associated tools and the fusion of advanced production and quality management. Based on the empirical studies reviewed, I concluded that no research had been previously made in the combined application of quality and lean management strategy and production structure amongst Hungarian agricultural machinery manufacturers. Using the literature summary as a basis, I defined the research questions to be used in the assessment of the hypothesis under investigation. Then I created the methodology related to my empirical research and described the steps and structures of the development of the questionnaires used in the primary researches. Based on the conclusions drawn from the results of the quantitative research conducted in parallel with the development of the questionnaire used in the examination of the maize harvester adapter manufacturers, I performed the targeted revise of this questionnaire and extended the examination to Hungarian agricultural machinery manufacturers.

As a next task, I processed and interpreted the data obtained from the answers to the questionnaires, with my hypotheses in mind. I conducted the primary research II involving Hungarian agricultural machinery manufacturers, which resulted in 59 completed questionnaires. In the analysis and evaluation of the data, I presented the extent of adoption of the production, quality and lean management specific to the sector and the presence of its toolkit concerning the industry examined. At the same time, I revealed the relationships between the dimension reduction variables and the thematic groups I established, for which I developed an assessment and measurement model. Using these attitudes, I performed an in-depth analysis of the correlations between quality, production structure and lean management concerning agricultural machine manufacturers. I took into consideration the definition of the structural and operational variables that have an effect on the presence of the three closely related fields of management (production, quality, lean management) in the domestic agricultural machinery industry. In my research, I also revealed the external effects of the application of streamlined production within a company on the competitive criteria of a supply chain. Summarising these, I answered the research questions and compiled the new scientific results.

As a conclusion of my thesis, I summarized the conclusions that can be drawn from the research results.

## 7. PUBLICATIONS ON THE TOPIC OF THE DISSERTATION


*Reviewed journal articles in a foreign language*

1. **Goda, A.,** Medina, V., Zsidai, L.: Manufacturing process development with 5S at different types of production. Mechanical Engineering Letters, Vol. 6., pp. 171-179. HU ISSN 2060-3789
2. **Goda, A.,** Medina, V., Zsidai, L.: Examination of the cob cracker adapter manufacturers' performance in Hungary. Mechanical Engineering Letters, Vol. 8., pp. 113-122. HU ISSN 2060-3789
3. **Goda A**. Medina V., Zsidai L.: Examination of suppliers for Hungarian cob cracker manufacturers and its comparative analysis with other industries. EPISTEME czasopismo naukowo-kulturalne, Kraków Nr. 25/2014, pp. 169-176. ISSN 1895-4421
4. **Goda A**. Medina V., Zsidai L.: Methodological development of the International Manufacturing Strategy Survey based on the case of the Hungarian maize pickers' manufacturer sector, Mechanical Engineering Letters, Vol. 14., pp. 64-71. HU ISSN 2060-3789
5. **Goda A**., Medina V., Zsidai L.: Examination of the Hungarian agricultural machinery manufacturer's product planning, quality management techniques and production coordination, Hungarian agricultural engineering 32/2017, pp.16-21. HU ISSN 0864-7410 (print) HU ISSN 2415-9751 (online)

*Reviewed journal article in Hungarian:*

1. **Goda, A.,** Lajos, A., Zsidai, L.: Lean menedzsment szerepe a mezőgazdasági gépgyártásban. Mezőgazdasági Technika, LIII. évf., 16-18. o. HU ISSN: 0026 1890
2. **Goda, A.,** Medina, V., Zsidai, L.: Lean menedzsment a mezőgazdasági gépgyártóknál. Megzőgazdasági Technika, LIX. évf., 2-5. o. HUISSN 0026 1890
3. **Goda, A.**, Medina, V., Zsidai, L.: Lean menedzsment és a globalizáció kapcsolatának vizsgálata a magyar mezőgazdasági gépgyártóknál. Gazdálkodás, 62. évf. 5. szám, 2018. 426-428.o.