**Doctoral School of**
**Business Informatics**

# Ph.D. Thesis Summary

**Tibor Kovács**

## Application of Multiple Criteria Decision Methods to Support Performance Improvement Programmes

**Supervisor:**

**Dr. Andrea Kő, Ph.D.**

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**Department of Information Systems**

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# Contents

## I. Background and overview of the research

The deterioration of the economic environment and the increased completion necessitated the group-wide improvement of business performance, therefore in the last decades many international manufacturing networks have embarked on multi-plant performance improvement programmes (Netland and Aspelund, 2014). These programmes are aimed to achieving step-change improvement of the worst performing sites and improving the entire network's performance at the same time. A well-established method of performance improvement is the implementation of capability – maturity models, of which, in the field of manufacturing World Class Manufacturing (WCM), Six-Sigma, and various Lean practices like Total Quality Management (TQM), a Just-in-Time (JIT) and Total Productive Maintenance (TPM) are the most prevalent. Measuring performance is crucial for the effective management of any business process or organisation, therefore it is fundamental for monitoring the effectiveness of performance improvement programmes. Appropriately selected performance indicators support setting relevant goals and monitoring their accomplishment as part of the business cycle, after all assessing the success of such performance improvement programmes.

The performance measurement related to manufacturing networks' performance improvement programmes is a relatively narrow field of research. Relatively few papers studied how an appropriately selected performance measurement system could support such programmes and what role it may play in their success. Netland and Aspelund (2014) in their paper highlight the need to for more research, that evaluates the success of these programmes using quantitative financial and non-financial performance measure. Measuring performance not only implies monitoring progress towards performance goals but could also contribute towards a healthy competition between sites, that stimulates knowledge transfer and improvements. Competition impose pressure on management, that facilitates the adoption of best practices (Ungan, 2005), however excessive pressure could inhibit knowledge transfer. This is especially prevalent if performance measurement focuses on relative and comparative measures, instead of the absolute ones and management perceives that the competition leads to only a few winners and many losers (Pfeffer and Sutton, 1999).

Neely, Gregory and Platts (1995) highlights two important aspects of business performance: effectiveness, and efficiency. The former describes to what extent the business meets its (internal or external) customers' needs, while the latter expresses how effectively it utilises the resources when provides products or services. (Wimmer, 2004). According to their definition, the performance indicator is a metric, that quantifies the effectiveness and efficiency of an activity or a process, while a performance measurement system is the entity of those performance indicators, that serves to measure the effectiveness and efficiency of a set of business activities or processes. Gunasekaran and Kobu (2007) suggest, that the purpose business performance measurement is a) identifying success, b) identifying if customer needs are met, c) better understanding of processes d) identifying bottlenecks, waste, problems and improvement opportunities, e) providing factual decisions, f) enabling progress and tracking it, g) facilitating a more open and transparent communication and co-operation. Akyuz and Erkan (2010) summarises criteria for a modern performance measurement system as following:

- based on the strategy and goals of the business,
- comprises a balanced set of financial, non-financial as well as strategic and operational indicators,
- enables to compare similar businesses,
- the aim, the data source and the calculation method of the indicators are clear,
- enables to set goals, summarising data, ranking and prioritise,
- free of overlaps,
- the indicators are rather defined as ratios that absolute numbers,
- facilitates to take a proactive approach, quick feed-back and continuous improvement,
- can be revised and supports organisational learning.

There are different approaches to calculate aggregate performance measures, of which popular method is using Multiple-Criteria Decision-Making (MCDM) models. Using this approach, the various performance indicators are the decision criteria, while the various business units, or sites are the decision alternatives. Multiple-Criteria Decision-Making is an important domain of Economics, that has received enormous developments since he middle of last century (Pomerol and Barba-Romero, 2000). The method ranks the alternatives based on the preferences of the decision maker, from which the best (most preferred) alternative and the overall rank could be determined using different methods and techniques. When determining the overall rank, it needs to be considered, that decision maker may assign different importance to different decision criteria. Since he seminal paper of Saaty (1977) Analytic Hierarchy Process (AHP) is an often used method determining the weights of importance, the same method is used in this research. Performance indicators are transformed using various functions, when determining the overall ranks. One of the most simple method to determine the overall rank is de Borda (1781) method, that is using an ordinal scale transformation. Utility functions describing the preference of the decision maker, are often used for the transformation, they help quantifying the differences in this preference by the changes of the performance indicator (Pomerol and Barba-Romero, 2000). The TOPSIS (Techniqe for Order Preference by Similarity to Ideal Solution) method (Hwang and Yoon, 1981) defines aggregate performance as an Euclidean distance from the best and worst alternatives in the multi-dimensional space of the performance indicators, and assumes a linear function between the performance indicator values and the decision makers preference. The preference relationships derived from the company's strategy could be described with appropriately defined utility functions. Pennings and Smidts (2003) states in their paper, that it cannot be ruled out that the shape of the utility function drives organisational behaviour, therefore it could be used to reflect the company's strategy, the non-linear relationship between the performance indicators and the preference relationships and after all drive the right behaviour. Having the appropriate utility functions defined, the overall rank could be calculated using weighted sum function, assuming the additivity of the decision maker's preferences (Fishburn, 1967).

Another important method measuring aggregate business performance is the performance benchmarking, that is based on the technique of Data Envelopment Analysis (DEA) (Charnes, Cooper and Rhodes, 1978). The aggregate performance is interpreted as an efficiency relative to the Technology, that is estimated from the data as the frontier of best performance. The method gives a conservative estimation for the frontier of best practice, the theoretical Technology is most often more efficient than this (Bogetoft 2012). This method can illustrate the financial impact of performance improvements, however dealing with those performance indicators, that cannot be easily classify as input or output measures could be problematic (Sherman and Zhu 2006). There are several requirements a performance measurement system must conform to, in this research especially important its ability to show improvements and to stimulate competition that drives improvements.

Syverson (2011) also highlighted the importance of competition in his study, investigating the internal and external factors of business performance measured via the indicator of productivity. According to him, competition increases productivity in two different ways: the less productive companies are driven out of the market, they close their operations, while it motivates management internally to implement those productivity improvement actions, that otherwise they would not do. Stagnation of productivity could be observed in those markets, where competition is weak. As for the key internal factors of productivity, Syverson mentions management capability, management routines, workforce competence, availability of capital and the level of capital investment, information technology, research and development, organisational learning, innovation and organisation structure. These internal factors could be described as business capabilities, they are defined by capability – maturity models. The fundamental goal of these models, described by Röglinger, Pöppelbuß and Becker (2012) in their paper of „Maturity Models in Business Process Management" is to outline the direction of business capability development and to define and describe in detail the various levels of maturity and their relationships. In the field of manufacturing and production prominent capability – maturity models are the: TQM, TPM, Lean and WCM methods. WCM is a manufacturing philosophy with the aim to eliminate the 7 cardinal sources of waste (Defects, Overproduction, Transportation, Waiting, Inventory, (unnecessary) Motion, (over) Processing) while respecting the customers, employees and suppliers (Schonberger, 1986; Shah and Ward, 2003). The WCM and the Lean practices are somewhat overlapped, they focus on different areas and practices (Schonberger, 1990; Flynn, Schroeder and Flynn, 1999). The seminal paper of Shah and Ward (2003) defines 22 Lean practices and cluster them to 4 groups. These groups have been identified and confirmed by principal component analysis.

- JIT – developing capabilities to effectively cope with fluctuating and complex demand.
- TQM – management routines and practices related to quality assurance and continuous improvement.
- TPM – processes to maximising equipment availability, preventing machine failures, in the end increasing efficiency
- HRM – processes related to human resources, such as training, problem solving and employee involvement.

Several research confirmed that there is a positive relationship between business capability and performance (Kadipasaoglu, Peixoto and Khumawala, 1999; Cua, McKone and Schroeder, 2001; Shah and Ward, 2003; Rahman, Laosirihongthong and Sohal, 2010; Taj and Morosan, 2011; Swink and Jacobs, 2012; Belekoukias, Garza-Reyes and Kumar, 2014; Fullerton, Kennedy and Widener, 2014; Marin-Garcia and Bonavia, 2015). In these researches, capability is measured as the existence or the level of maturity of key business processes (such as WCM or Lean practices), while business performance was most often measured by various survey instruments. Using survey instruments could somewhat weaken the results of these research due to the subjectivity of the method. There are negligible those studies, that measures business performance based on objective performance indicators. Among these research, that investigated the relationship between business capability and performance, worth to mention the paper McCormack, Bronzo Ladeira and Valadares de Oliveira (2008), investigating 478 Brazilian companies using survey instruments and Partial Least Squares Structural Equation Model (PLS-SEM) method. Their research confirmed, that the relationship is significant and positive. Demeter and Losonci (2011) studied the relationship between Lean practices and business performance and the results of their research demonstrated, that financial indicators cannot always reveal the benefits of such practices, however operative performance indicators indicate a significant and positive relationship. A recent literature review by Negrão, Filho and Marodin (2017) somehow balance this picture of positive capability – performance relationship. The research papers they reference have diverse results and identify certain research that reported negative relationship between lean practices and performance. It is unknown, if the subjectivity of the survey instruments has influenced these diverse results?

This research investigates those methods, that could support the performance improvement programmes of international manufacturing networks, specifically measuring, comparing, ranking and developing business performance. It is based on the case study example of a multinational company - SABMiller plc – that had many years of experience implementing Lean practices in their manufacturing plants. As part of the performance improvement initiative, the company has implemented a performance competition system and ranked their plants regularly. However, the performance competition has not achieved its full potential, due to the simplicity of data analysis methods, and the positive relationship between the implementation of Lean practices and performance could not be scientifically confirmed either. This research wanted to provide support in this field and develop knowledge that could be relevant for other companies too, developing their performance.

## II. Research questions

The research questions have been defined recognising the needs of the case study company and identifying potential research gaps of the current literature. The company of the case study wanted further developing its performance measurement and ranking system, providing better support for its improvement programme and wanted to demonstrate the effectiveness of its capability development programme. With regards to the potential research gaps, this research is desired to contribute to the few papers that investigated the effectiveness of performance capability – performance relationship using objective performance measures.

Therefore, the research questions related to the aggregated performance measurement methods were formulated as:

- Q1: which performance aggregation system could support most effectively the performance improvement programmes?
    - Q1a: which represents aggregate performance the most accurately?
    - Q1b: which could be used to monitor progress in time?

While the research questions connected to the capability – maturity relationships are:

- Q2: How strong is the relationship between Lean capabilities and performance in the context of the case study?
    - Q2a: is this relationship stable in time?
    - Q2b: are there Lean capabilities that may have a disproportionate effect on performance?
    - Q2c: is the implementation of Lean practices affects all performance areas and indicators equally?

## III. Research methods

This research combines two methods: case study methodology and quantitative data analysis: Multiple Criteria Decision Methods, performance benchmarking (DEA) and PLS-SEM. Case study methodology is a widely used technique for analysing complex management problems (Eisenhardt, 1989; Yin, 2003), in this research it is used interpreting the results of the quantitative analysis in the context of the case study, with the help of interviews and performance reports. Case study methodology helps to understand the dynamics of processes in one specific case, from which generally applicable learnings could be made. It is important to determine; how representative the findings of the research are? Could those be extended to other fields or industries, and what restrictions may be applicable for these generalisations. The generalisability of this research is limited by the fact, that it is based on a single company, that has a relatively homogenous culture, and specific approach to problem solving and operations. On the other hand, the company has implemented a Lean methodology, that is common to other industries and employed consultants, who ensured the transfer of knowledge and best practices between companies and industries. Furthermore, the sites of the case study have spread over five continents and applied both mass production and batch processes (food and beverage). All things considered, the findings of this research may be extended to other consumer goods companies.

The practice-oriented case study research is frequently organised around a business problem, and it is aimed to supplement the knowledge needs of practitioners dealing withe these problems. During the research the methodology described by Dul és Hak (2009) has been followed, that: 1) the business problem to be defined as precisely as possible 2) to be established, what activities have already been undertaken to solve the problem, what have been their intensity and effectiveness? 3) to be determined that additional knowledge that is required to solve the business problem and 4) to prioritize this knowledge requirement. For the research, that is aimed at testing and confirming theories, experiments must be preferred over other methods. In case it is not feasible to carry out experiments – like in this research, where experiments could not be done due to working with an operating company – time series analysis (longitudinal studies) or comparative methods could be followed (Dul and Hak, 2009). In this research, when interpreted the results of quantitative analysis, specific cases are selected and compared, as well as their change over time is  In the theory oriented research, the sufficient and necessary conditions, as well as deterministic relations between concepts could be tested, and it is important, that these conditions and relations must have business relevance. (Dul and Hak 2009). In this research, multi-dimensional scaling is used to investigate, what are those Lean practices that are implemented similarly and/or differently in the case study. The deterministic relations between Lean practices and performance is evaluated using PLS-SEM method.

It could difficult to access information and data for the research, due to confidentiality restrictions or lack of knowledge about their sources (Yin, 2017). As the author of this thesis was working for the case study company, less problems have been experienced in this field. The way the company was operating was well known for the author, therefore was able to access necessary information and relevant personnel. The data was anonymised due to confidentiality requirements and has been presented in a way that in no ways confidential information about the company or about specific plants could be retrieved. The data was analysed following the four methods Yin (2017) proposed: pattern matching, and a specific version of it: explanation building methods were used when comparing and interpreting the results of the various multi-dimensional decision models; for the latter explaining the concepts that may be behind those patterns. The third method: time series analysis was used to evaluate the capabilities of the various multi-dimensional decision models to display changes in performance over time and to analyse the differences in the results of multi-dimensional scaling and PLS-SEM methods over time. The fourth method: logic models, that are aimed at revealing cause – effect relationships, have been used in analysing the relationship between capability and performance.

## IV. Results of the research

## Comparison of performance aggregation methods

Aggregate performance ranks and aggregate indicators have been calculated for 73 sites of the case study company, using four different multiple-criteria decision models and the DEA method, in order to determine which one of them could support best the performance improvement programmes. 14 performance indicators have been used for the multiple-criteria decision models, those have also been used by the case study company for their management and performance competition system. This set of indicators has been extended with headcount productivity and maintenance cost indicators for the DEA models (Table 1).

1. Table Performance indicators used in the research

| performance category | details | no. indicators | multiple-criteria decision model | performance benchmarking (DEA) |
|---|---|---|---|---|
| quality | conformance to internal specification, analytical results | 7 | yes | no, but poor performers excluded from model |
| water and energy usage | usage ratios | 3 | yes | yes |
| material loss | loss rates | 2 | yes | yes |
| OEE[1] | overall productivity, machine failures | 2 | yes | indirectly |
| headcount productivity | headcount per unit production | 1 | | yes |
| maintenance cost | maintenance cost of manufacturing equipment | 1 | | yes |

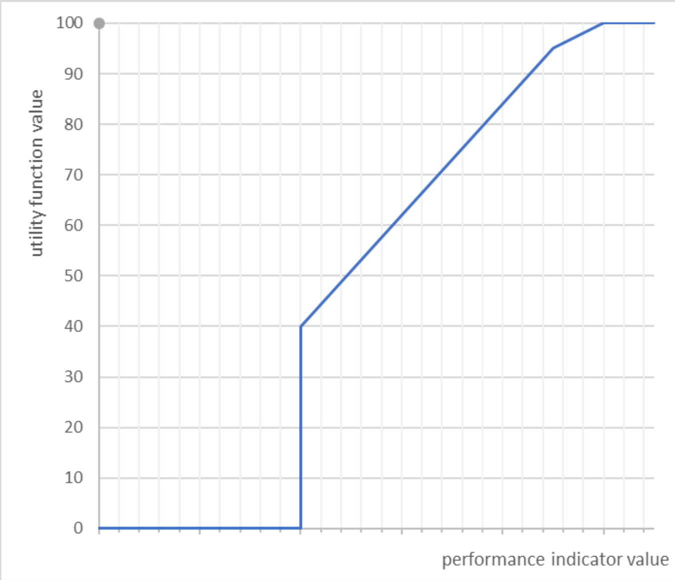
Comparing the DEA results with the results of the multiple-criteria decision models, it is visible, that the former differentiate the sites much less than the latter. The DEA method rates in most cases maximal productivity those sites, that the multiple-criteria decision models rate only as good performance (not excellent), and its calculates in general higher performance rating. The reason behind this phenomenon is the way the linear programming calculates the frontier and the productivity of the individual sites: it is using sites that have similar combinations of input and output measures, therefore the more numbers of inputs and outputs are used to define the model, the more sites will appear on the frontier with maximal productivity (Bogetoft, 2012). Reducing the numbers of inputs and outputs could help in this problem, however it could also reduce the validity of the calculations, as sites with very different input – output mix may be compared. Those performance indicators, that could not

[1] OEE – Overall Equipment Effectiveness

be categorised as inputs or outputs (e.g. quality), can only be used as selection criteria, to decide if a site could be included in the set that is used to calculate the frontier[2]. Furthermore, calculating the productivity of those sites, that have been excluded from the model is difficult. The single benefit of the DEA method is, that the financial dimension of productivity improvement opportunities could be presented in a suggestive way.

The evaluating of the various multiple-criteria decision models' results reveals, that the Borda ranks give no information about the proportion of performance differences and therefore they could unnecessarily enlarge them, as it may suggest, that the proportion of difference between the ranks are equal, which is seldomly true. The Borda rank considers each performance indicator equally important, that may not be aligned with the company strategy. Using weights for recognising the differences in importance – but preserving the ordinal scale of the Borda method – would not change the results drastically. ***Answering research question Q1: distinctly designed utility functions with weights of importance determined using the AHP method could support most effectively the performance improvement programmes***. The shape of the utility function, in line with the company strategy has been designed, that it: a) encourages the sites to achieve a threshold performance level for each indicator by the function mapping zero value for performance values below threshold and b) above a set limit of excellent performance the utility function does not motivate further improvements (Figure 1). ***Regarding research question Q1a: TOPSIS method using weights of importance determined using the AHP method could give the more realistic picture about aggregate business performance, assuming linear relationship between performance indicators and their utility.*** The utility functions, that are specifically designed for supporting performance improvement programmes would give – deliberately – a distorted picture.

[2]It would be wrong to assume, that quality and output are interchangeable measures. According to this, more but worse quality product would mean equally efficient combination, as less but better quality, that would have serious consequences for the company.




1. Figure The utility function used in the research

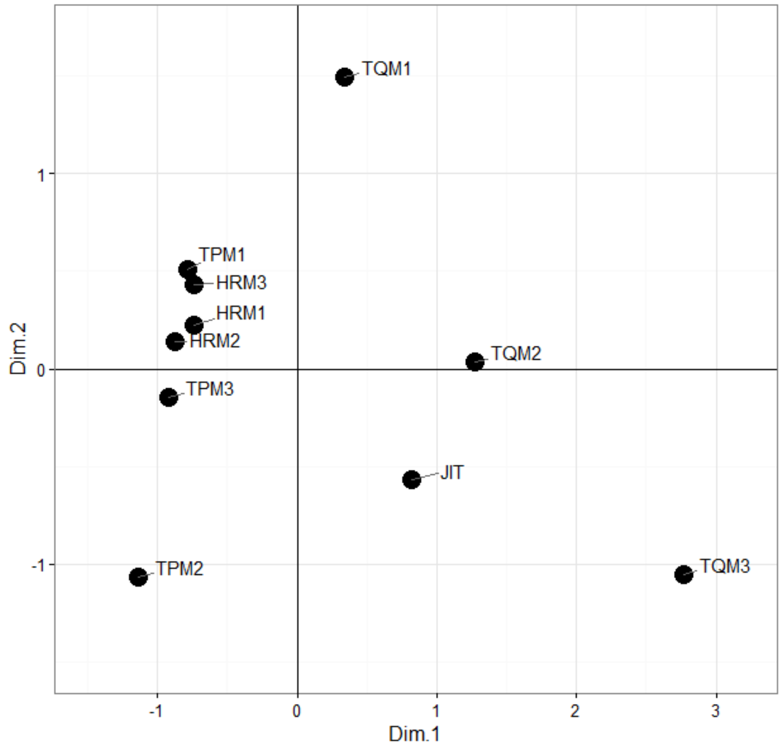
Performance ranks, and especially methods based on Borda ranks are not suitable to monitor performance over time. While the number of positions is fixed, this leads to a zero-sum game between the participating sites, one site can only improve its position at the expense of the others. This would hinder knowledge sharing and cooperation. ***As for research question Q1b: the TOPSIS or the distinctly designed utility functions, both using weights of importance determined using the AHP method, on the other hand are suitable to track changes in performance over time, even through many years, if the limits are carefully defined.*** The best and worst performance limits for the TOPSIS method, or the maximum – minimum values for the utility functions must be defined in such a way, that no site would be able to exceed it. Presenting the results graphically – both ranks and proportions of performance differences – would create optimal conditions for competition. These methods could primarily be applicable for situations, when many business units perform similar activities, their performance indicators are comparable and sharing these between each other is feasible – an example being the manufacturing networks. It is however not impossible to apply these methods by businesses operating separately in the market; a good example to provide an anonym platform for comparing key performance indicators would be the one established as part of the initiative „Business Innovation and Virtual Enterprise Environment" sponsored by the European Committee (Diamantini, Potena and Storti, 2013)

## Relationship between individual capability areas

Prior to analysing the capability - performance relationship, the relationship between the individual capability areas (Table 2) have been analysed, to evaluate if their level of implementation is similar and simultaneous, and if they could be combined for further calculations. Non-metric multi-dimensional scaling method: ALSCAL (Takane, Young and de Leeuw, 1977) has been used for this analysis. The results (Figure 2) confirmed, that the three Lean practices that are part of the human resources management (HRM) bundle are similar to each other, they are implemented simultaneously. Furthermore, two Lean practices that are part of the total productive maintenance (TPM) bundle: 5S (TPM1) and autonomous maintenance (TPM 3) are also similar to the HRM practices, they may share similar capabilities. However, this latter cluster is not stable over the three individual years, that may be caused by the inaccuracy of the method or by insufficient number of observations. Practical application of this method could provide additional information to the capability development-based performance improvement programmes, to better understanding the Lean practices, and optimising their implementation.

2. Table Capability areas of the case study

| Lean bundle | Code | Capability area | description |
|---|---|---|---|
| HRM | HRM 1 | Focused improvement | ensures continuous improvement by analysing problems implementing solutions |
| | HRM 2 | Teamwork | empowering teams to achieve common goals self-sufficient |
| | HRM 3 | Performance measurement and control | ensures that process performance is immediately visible and corrective actions are taken real-time |
| JIT | JIT | Manufacturing flexibility | establishing the capability to cope with fluctuating and complex demands. |
| TPM | TPM 1 | 5S | Workplace cleanliness, order, standardisation and simplification of work |
| | TPM 2 | Asset management | maximises equipment availability, reliability in the most cost-effective way |
| | TPM 3 | Autonomous maintenance | operators take direct responsibility for and maintain the equipment they operate |
| TQM | TQM 1 | Quality management | ensures defect-free products meeting the highest quality standards |
| | TQM 2 | Environmental management | Sustainable use of finite resources, identification and elimination of environmental impacts |
| | TQM 3 | Health-and-safety management | ensuring safe working environment by identifying risks and eliminating them |

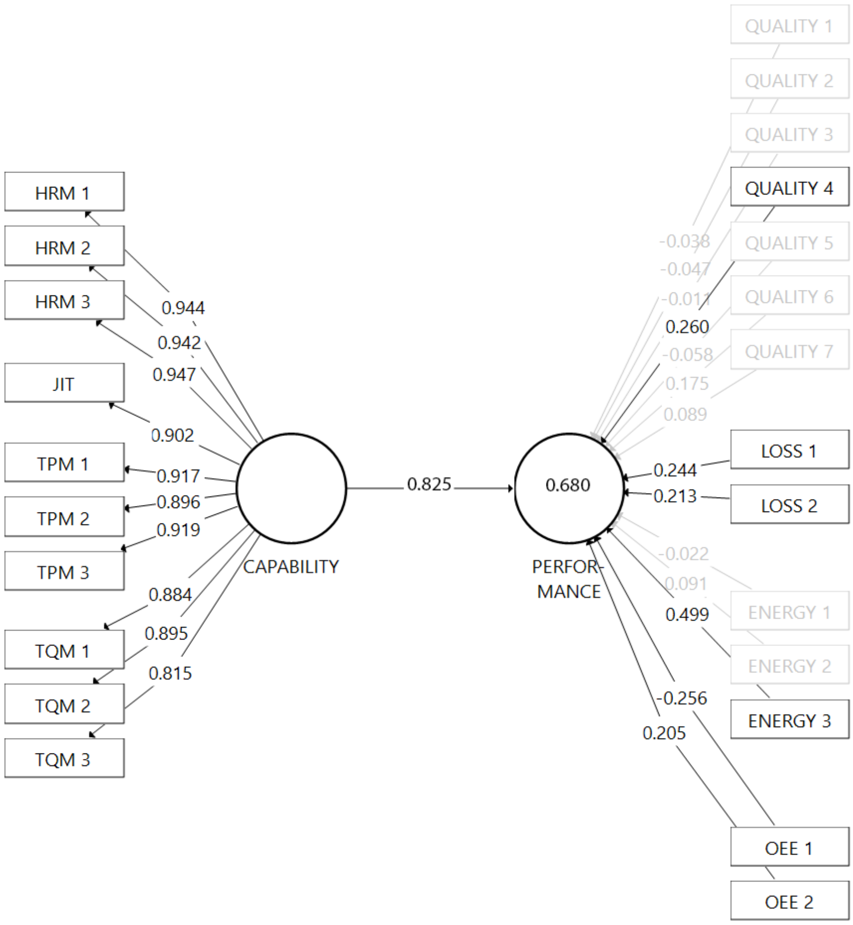



2. Figure ALSCAL results of individual capability areas (2014-2014 years combined)

## Relationship between capability and performance

Four PLS-SEM models have been created and evaluated to analyse the relationship between capability and performance, using data from 80 business units (sites), of the maturity levels of 10 individual capability area measured as self-assessment using 1-5 Likert scale, and the z-score normalised values of 14 performance indicators; for the years 2014, 2015, and 2016 combined and individually. The construct: CAPABILITY, has been modelled as reflective measurement model, while the construct: PERFORMANCE has been modelled as formative measurement model. The maturity levels of the capability areas are highly correlated, they are somewhat interchangeable, while the correlation between the performance indicatiors are weak, therefore they are not interchangeable, the describe individual aspects of the construct performance. As for the first, most simple model (Figure 3): the path coefficient representing the hypothesized relationships for CAPABILITY → PERFORMANCE was calculated as 0.825, (three years combined) while the coefficient of determination ($R^2$), measuring the model's predictive accuracy was 0.680. Both values are very high, even compared with the results of other researches, ***answering research question Q2: that the relationship bteween the implementation of Lean practices and performance is strong and positive in the context***

***of the case study.*** This is in line with earlier research findings (Cua, McKone and Schroeder, 2001; Shah and Ward, 2003).



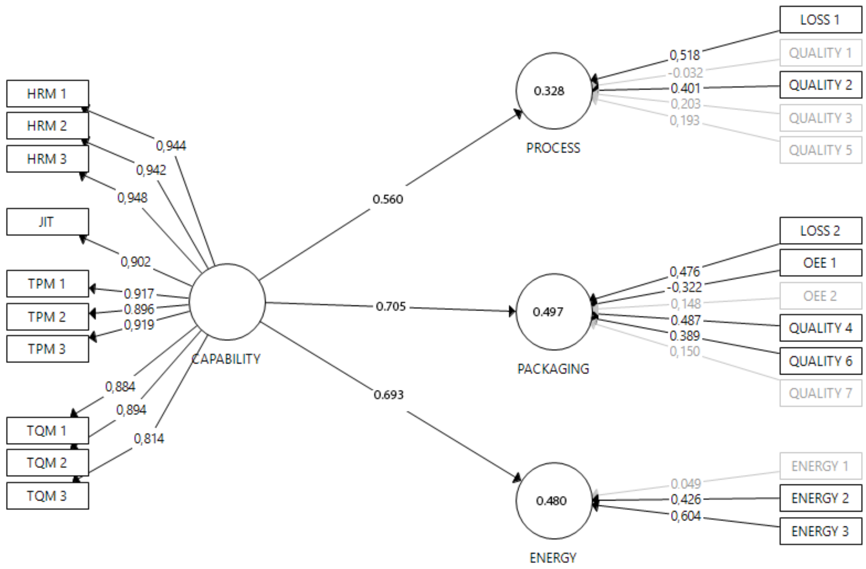

3. Figure results of model no. 1 (2014-2016 years combined)

Analysing the individual years separately shows, that the path coefficient is getting weaker over the years, ***answering research question Q2a, that the value of the path coefficient may changes over time.*** This finding is in line with the descriptive statistical results, that the maturity levels have not changed during the three years while performance indicators have shown significant improvements. This change over time could be the result of several factors: 1) the self-assessment may be inaccurate, the sites may under-rate their levels of maturity, the achieved capability improvements are not acknowledged 2) performance may be improved by means other than capability development, e.g. by investment projects or by implementing different technologies, although the results of the fourth PLS-SEM model suggests, that investments has much less effect on performance than capability (and this effect is negative) and it does not affect the capability – performance relationship. 3) Finally it could be caused by the phenomena that Netland and Ferdows (2016) describes as S-curve effect. Based on this theory, during the capability development journey performance changes at differing rates, there exists intervals, where small change in capability results to large performance improvements.

***This model unfortunately cannot answer research question Q2b – if there are specific Lean capabilities that affect performance disproportionately.*** Because the CAPABILITY construct had to be modelled as reflective measurement, its variables describe jointly the construct and they are to some extent interchangeable.

The second PLS-SEM model (Figure 4) analyses, if capability affects specific performance areas differently. Performance indicators have been assigned to three different groups: the first group (PROCESS) is the area of the plant that processes raw materials to liquid beverage and applies batch process, the second is the area, (PACKAGING), that packages this liquid and applies mass production processes, while the third area (ENERGY). groups those performance indicators, that measure the energy efficiency of the whole plant. As area specific Lean maturity data was not available, the level of Lean practice implementation (CAPABILITY) was modelled if it was uniform across the whole plant. Path coefficients in this model (Figure 4) are somewhat smaller, than in the previous model, but still significant. The smallest path coefficient was measured for the performance indicators of the PROCESS area, suggesting, that this area may depend least from the Lean practices and/or it may require additional knowledge, that is not covered by the Lean practices. Problem solving techniques, total productive maintenance, teamwork and other Lean practices still have significant effect on performance, but additional capabilities like specific methods for the optimisation of batch processing may be required for further improvements. The highest path coefficient was measured for the area: (PACKAGING), this is the area that, based on experience utilises Lean practices most, many of them - like quick change-over technologies (SMED) or maintenance practices - have been specifically developed for this area. ***This answers research question Q2c: Lean practices could affect specific performance areas differently, depending on how much the area rely upon the Lean practices or other area specific knowledge.***

The last two models explored, how other factors, like the size of the plant or the level of capital investment (approximated with the depreciation levels of the sites) may influence performance or the capability – performance relationship. The results suggest, that plant size has no influence either on performance or the relationship between capability and performance. Between level of investment and performance significantly smaller and negative path coefficient was measured, than between capability and performance, and it had no moderating effect on the capability – performance relationship. This confirms, that the implementation of Lean practices influences business performance most.




4. Figure results of model no. 2, by performance areas (2014-2016 years combined)

Measuring path coefficients in this way, by specific process areas could provide opportunities to practitioners to analyse the effectiveness of Lean practice implementation on performance – overall and by area, evaluate the validity and accuracy of Lean maturity self-assessment, and to identify those areas – with the smallest path coefficient – where Lean capability implementation does not result to the required performance improvements. The PLS-SEM method, that is mainly utilised in research could get a new, practice-oriented application to provide support to performance improvement programmes.

In summary, performance improvement programmes, including the ones that are based on capability development, could significantly benefit from the application of modern data analysis techniques Managing any project or intervention would require information about its effectives. Based on the results of this research, TOPSIS or the distinctly designed utility functions, both using weights of importance determined using the AHP method are recommended to measure and monitor aggregate business performance. Furthermore, it is recommended to use ALSCAL multidimensional scaling method to analysing the relationship between the capability areas and the PLS-SEM method to measure the relationship between capabilities and performance. These methods could provide additional information to performance improvement programmes, supporting their success.

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