KEY PERFOMANCE INDICATORS (KPI) FOR THE IMPLEMENTATION OF LEAN METHODOLOGIES IN A MANUFACTURE-TO-ORDER SMALL AND MEDIUM ENTERPRISE

Markus L. Stamm
Thomas Neitzert

School of Engineering
AUT University
Auckland, New Zealand
mstamm@aut.ac.nz

ABSTRACT
This paper presents a key performance indicator (KPI) concept for the implementation of Lean methodologies in a manufacture-to-order (MTO) small and medium enterprise (SME). Within a case study the concept is developed and improved. The purpose of the measurement system is to monitor the early Lean implementation process.
The paper explores the current literature about Lean performance measurement and discusses the critical success factors of a Lean implementation. It is suggested to integrate the performance dimension "leadership" into a KPI concept. The KPI concept consists of five dimensions: leadership, quality, costs, time and people respectively organisation. Additionally the Lean metrics "Process Velocity" and "Value Velocity" are presented and adapted to the specific requirements of a MTO environment. The application of the KPI concept in the case study is discussed. The benefit of an early integration of an appropriate KPI system during a Lean implementation could be confirmed.

Keywords: Lean Production, Key Performance Indicators, leadership

INTRODUCTION

Womack, Jones and Ross revealed in their book "The Machine That Changed the World" (Womack et al., 1990) why Toyota seems to exceed their Western competitors in productivity and quality. Sparking further research (e.g. (Emiliani, 1998), (Emiliani, 2004), (Flinchbaugh and Carlino, 2006), (Sobek, ?), etc.) and implementation efforts of Lean manufacturing methodologies all over the world (e.g. GM and Ford (Liker and Meier, 2006), Porsche and Pratt & Whitney (Womack and Jones, 1996)) the so-called 'Toyota Way' (Liker, 2003) also found supporters and applications beyond the mass-production sector, such as low-volume manufacturing and service environments like healthcare, which are according to Hines et al. still in early stages of their lean evolution and under-researched (Hines et al., 2004). In addition research has already been done concerning the adaptability of lean tools and principles to SMEs (Small to Medium Sized Enterprises) (Achanga, 2005) (Green, 2004). Although, according to these authors, further investigations are necessary. Especially in New Zealand (NZ), where 98.74% of companies have less than 50 employees and the average number of employees per enterprise as of February 2005 is 5.2. (Ministry of Economic Development, 2006), and where the rapidly changing international environment and the emergence of large developing economies, such as China and India, forces the manufacturing industry to find specialised niche markets (NZTE (New Zealand Trade and Enterprise), 2006), the importance of this research area is obvious.

A further deficiency of research has been noted by Bourne (Bourne, 2000) in the practical implementation and use of performance measurement systems. Measures regarding various lean activities have already been developed (Kutucuoglu, 2001) (Nakajima, 1994). However, it has been suggested that these measures, although beneficial as monitors, are either not suitable as sole performance measures or require further research (Kutucuoglu, 2001).

Furthermore, pressure of global competition emphasizes the need to find appropriate measures for total productivity (Hannula, 2002).

Research Objectives

Considering the lack of research concerning the implementation of Lean in SMEs, the implementation of Lean principles in a low-volume (or manufacture-to-order) environment and performance measurement, this paper tries to present a KPI concept for a Lean implementation in a NZ MTO SME based on a case study. The main target of this paper is the determination of KPIs that are the most useable and most suitable for a “manufacture-to-order” SME to support and monitor its early Lean implementation process at an operational level.

Research Methodology

The research methodology adopted entails the use of published literature and cooperation with RPM International Tool and Die, a NZ tool manufacturing SME (<50 staff members) that has already been implementing Lean methodologies for about 20 months. RPM already started with the measurement of KPIs (First Time Instances, Jobs on Time (described later)) 4 months before the research project began. These KPIs have been monthly generated for every manufacturing cell and were continued to be evaluated with regards to their effects and manageability.

The research methodology consisted of the following steps:

- Literature review in the correspondent field of research
- Observations of shop-floor activities to get a deeper understanding of the specific “manufacture-to-order” characteristics
- Interviews with staff members and team leaders
- Evaluation of existing manufacturing data to check the “information availability”
- Testing of KPIs and their usability in management meetings

These activities were performed in a similar sequence (though with some overlaps).

LITERATURE REVIEW

Requirements and prerequisites of metrics

In a first step general requirements of metrics are summarised to provide a solid knowledge base for the development of the necessary KPIs.

Neely et al. (Neely, 1994) regard performance measurement as the quantification of the effectiveness and/or efficiency of an activity over a given time period whereas the essence of performance could be determined as the creation of value with certain provided assets including human, physical and capital resources (Carton, 2006).

According to Hannula (Hannula, 2002) useful measures in industry are always compromises between validity (ability of a measure to measure what it is intended to measure), reliability (consistency of measurement results), relevance (value and usefulness for the users of the measure) and practicality (cost-effectiveness, i.e. is the effort to generate the measures justifiable). In this paper, practicality is seen from the point of view of the constraint of limited resources in a SME as one of the most important criteria for any performance measure during an implementation process of Lean methodologies.
Senge (Senge, 1990) notes that a system responds to how it is measured. When measures badly affect a system it results in "creative tension" which affects a person being attempted to do the right thing at the expense of measures. Therefore the choice of proper measures consistent with desired behaviours and organisational goals is vital to performance measurement. Inappropriate measures encourage dysfunctional behaviour, fuzzy judgement, sub-optimization and manipulation (Senge, 1990). An important feature of the Japanese view of the management of measures is according to Hiromoto (Hiromoto, 1988) that it should play more of an "influencing" role than an "informing" role and be subservient to corporate strategy, not independent of it.

Levinson and Rerick (Levinson and Rerick, 2002) define three standards for appropriate performance measurements:
1. Measurement should be objective, could be precisely defined, and could be measurable with numbers.
2. Performance should be controlled by people or department that is measured.
3. The performance measurement must help the company to meet its goal.

Maskell (Maskell, 1991) postulates the following characteristics for a performance measurement system in a world class manufacturing enterprise:

- They are intended to foster improvement rather than simply monitor performance.
- They change over time as needs change.
- They are simple and easy to use.
- They provide fast feedback to operators and managers.
- They vary between locations.
- They are directly related to the manufacturing strategy.
- They primarily use non-financial measures.

According to Lind (Lind, 2001) who conducted a longitudinal case study to understand the financial and non-financial measures of a World Class Manufacturing company revealed that non-financial measures were used for the day-to-day control, whereas financial measures were used for long-term control.
Lind (Lind, 2001) concludes it is important that "frequency of information matches the manufacturing time cycle. If the manufacturing throughput time is short, information must be available continuously, in contrast to large throughput times when information can be reported weekly or even longer."
Shinkle et al. (Shinkle et al., 2004) suggest the following Key Lean Manufacturing metrics: delivery performance percent, customer returns (in PPM), first time quality (FTQ) percent, scrap percent, total product cycle time (dock to dock), total product cycle time improvement percent, parts per labour hour, attendance rate, continuous improvement participation percent, etc. Maskell (Maskell, 2004) presents for the value stream performance a collection of measures categorised into strategic, value stream and cell or process measures.

Critical success factors during implementation

Achanga et al. (Achanga, 2005) determined in their investigation of ten SMEs in the UK critical success factors for the implementation of lean methodologies in SMEs. As shown in Figure 1 the four main success factors are leadership, finance, organisational culture and skill and expertise. The importance of an appropriate performance measurement system has not been directly mentioned in this context. However, Åhlström (Ahlstroem and Karlsson, 1996) observed that the management accounting system has been a major impediment to the desired changes towards a lean manufacturing strategy, because the traditional way of measuring productivity indicated increased costs, while figures like WIP, quality and time accuracy showed positive signs of performance improvement. Besides Åhlström mentions, that strategic decisions of management (refers to leadership), whether and how the Lean implementation should continue, are also based on the results of the measurement system. Hence, the adaptation of the metrics must happen quite early in the implementation process.

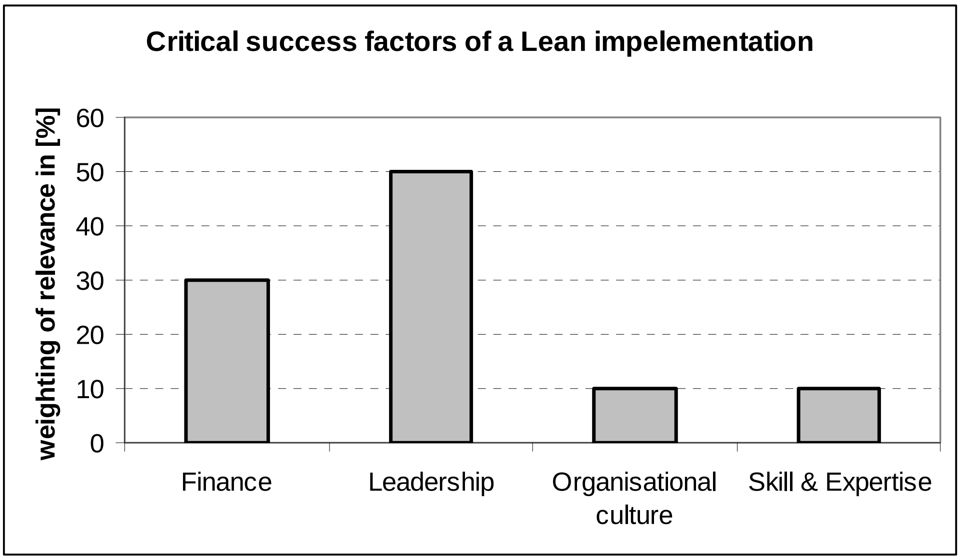

Figure 1: Critical Success Factors for the implementation of Lean Manufacturing (Achanga, 2005)

Furthermore Liker (Liker and Meier, 2006) mentions that the difference between success and failure concerning the Lean implementation starts with leadership respectively with the commitment and active support of the management. Also Flinchbaugh (Flinchbaugh, 2006) concludes that Lean principles require more change in management than it requires in front-line employees. A survey published by the Lean Enterprise Institute supports this statement revealing that the main obstacle of Lean implementations is the middle management resistance to change (Lean Enterprise Institute, 2007). Hence in the opinion of the authors it is essential for a sustainable implementation to monitor the involvement of the management.

CASE STUDY AND KPI CONCEPT

Challenges of a manufacture-to-order environment

For a better understanding of the specific characteristics of a MTO environment, the following differences to a mass-production company could be identified by the authors:

Changing customer takt (dependent on required shipment date)
As a rule, every product is unique or at least identical products are manufactured rarely. Therefore also the requirements of the customer vary from product to product, including the required shipment date. That is why a levelled customer takt in terms of mass-production is very difficult to realise. Besides cycle times are often not known at the beginning of a project because of the uniqueness of the correspondent components.

No clear material flow
Every product can consist of a different number of components and also the components themselves are different concerning the necessary manufacturing processes and manufacturing cycle time.

Slightly different definition of Work in Process (WIP)
Several authors stress that decreasing the level of inventory is a crucial principle of Lean Thinking (Liker and Meier, 2006),(Womack and Jones, 1996). Because every product is manufactured according to an order of a customer, there is no inventory in terms of finished products. Furthermore, because of the uniqueness of the products and their components, raw material is mostly purchased project-oriented. Hence, the existing level of raw material inventory can also be neglected in this case study. Though, taking semi-finished parts between manufacturing processes into account, a slightly different definition of WIP in a manufacture-to-order company is necessary.

Different loads on processes, no clear pitches (work units)
As already mentioned the work loads on the processes vary because of the changing cycle times which are additionally difficult to forecast. These accuracies of forecasting and the wide standard deviation of the process duration (e.g. in our case study the cycle time at the CNC machines can be between several minutes and up to 40 hours) also exacerbate any standardization efforts towards clear pitches.

Dynamic scheduling / many changes
According to the already mentioned characteristics, scheduling is dynamic involving many changes during a project’s progress.

Quantification in a manufacture-to-order environment
To illustrate the specific characteristics of a manufacture-to-order environment the example of the production of an injection molding die is presented in the following. The production of injection or press tools can be seen as a special case of the manufacture-to-order environment.
Usually an injection molding die consists of standard vendor parts (e.g. screws, where no further treatment is required), semi-finished parts (e.g. guide pins, ejector pins that need to be fitted to the required size) and unique components (e.g. those defining the cavity). Latter components can usually pass several manufacturing steps:
- rough cutting of raw material
- heat treatment
- wire-cutting and/or CNC machining of the cavity details
- grinding
- sparking
- polishing

These manufacturing processes can be generalized with the index

i :=1;2;3;4;… number of the manufacturing process with m := number of processes
The different components are defined in this example as:
j := 1;2;3;4;…number of the component with n := number of components
According to this definition the component j=1 can pass through the manufacturing processes i=1, 3, 4, 6 (see Figure 3). The manufacturing processes i=2 and i=5 (e.g. heat treatment and sparking) are not necessary. Figure 2 illustrates that several components (j=1,…,6) need different cycle times in the process i=1 (e.g. rough cutting the raw material).
The necessary manufacturing time for the component j at the process i can be summarised as:

$T_{ij} = t_{S,ij} + t_{P,ij} + t_{Q,ij}$ with

S: Setup time
P: Processing time (actual value adding time)
Q: Queuing time (time between two processes minus the setup time)

The total necessary manufacturing time for the component j for all processes can be summarised as:

$\sum_{i=1}^{m} T_{ij} = T_{Tj}$ (Index T means Total)

The component being on the "critical path" and constrains the total manufacturing time of the whole die can be characterized with:

$\max\{T_{Tj}\} = T_{Tj,\max}$ with j=1;2;3;4;…;m and m:= number of parts

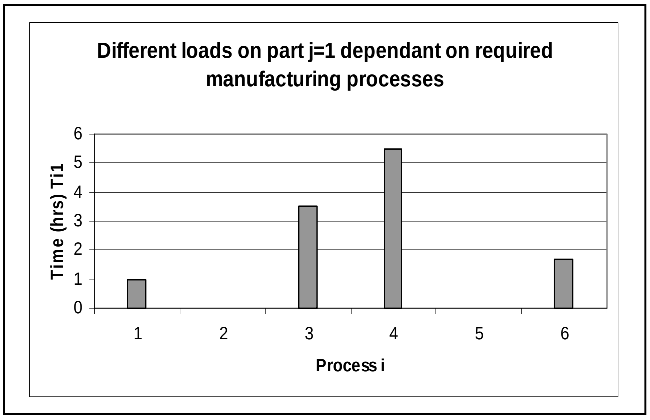

Figure 3: Process time of several processes for part j=1, e.g. rough cutting

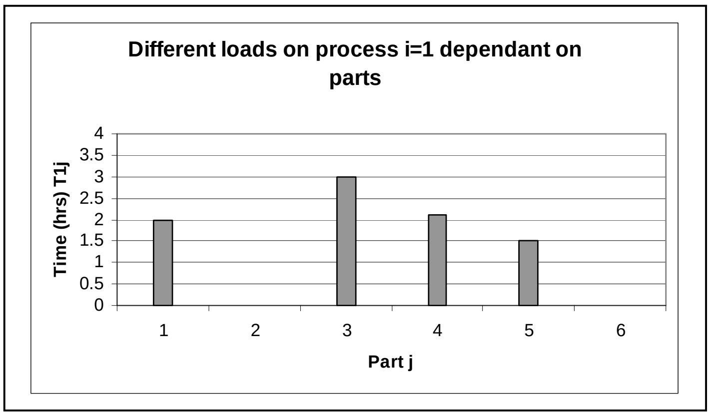

Figure 2: Process time of several parts in the process i=1

These characteristics were determined during observations of the shop-floor activities, a detailed process analysis, and interviews and informal discussions with the management team of the industrial partner.
Additional constraints affecting not only manufacture-to-order companies but also SMEs in a wider sense are (in comparison with a larger company):

- less resources

- several functions are held by one person
- no investments in complex ERP systems

Development of KPI concept

The development process of the KPI concept roughly followed the three phases mentioned by Bourne et al. (Bourne, 2000): design of the performance measures, their implementation and their use. During the development and selection of appropriate KPIs the criteria “relevance” (in terms of adherence to the corporate goals and support of the lean principles) and “practicality” (in the sense of applicability of the measures with basic tools like white-boards, paper or simple data processing software like spreadsheets) were chosen. Hudson (Hudson et al., 2001) presents in his literature review an overview of the commonly cited respectively mentioned performance measurement dimensions. Quality, time and flexibility are mentioned as operational measurement dimensions. Apart from that, finance, customer satisfaction and human resources are also cited by Hudson as critical measurements. Hence those dimensions (especially the operational and financial dimensions) need to be integrated into a correspondent KPI concept. Besides the critical success factors must be taken into account for the KPI concept. Because this paper focuses on the operational implementation of Lean principles, neither the strategic dimension nor the dimension “end-customer satisfaction” is covered in detail. Nevertheless the authors want to emphasize the importance of those dimensions, which certainly should be taken into account in later phases of the Lean implementation.

The KPI concept takes into consideration the traditional performance dimensions focusing on the Lean principles and additionally covers the performance dimension “leadership”, which is derived from the critical success factors (Achanga, 2005). There is no KPI concept known by the authors integrating “leadership performance” in the context of a Lean implementation project into the measurement system. Because leadership turns out to be one of the most important critical success factors according to a study by Collins (Collins, 2001), analysing the reasons of success of ‘Fortune 500’ companies, the integration of leadership performance is in the opinion of the authors essential. Therefore, the commitment of the management respectively of the change agent(s) is necessary to be monitored and their involvement and performance during the Lean implementation which can take according to Womack (Womack and Jones, 1996) more than 5 years. Examples of such measures are e.g. the number of Lean seminar attendances by management members, the active involvement of managers in kaizen activities or the adherence to production planning & management meetings having Lean implementation efforts on their agenda.

In total the presented KPI concept consists of the operational performance dimensions costs, quality and time, the people respectively organisation performance, the leadership performance and specific Lean metrics.

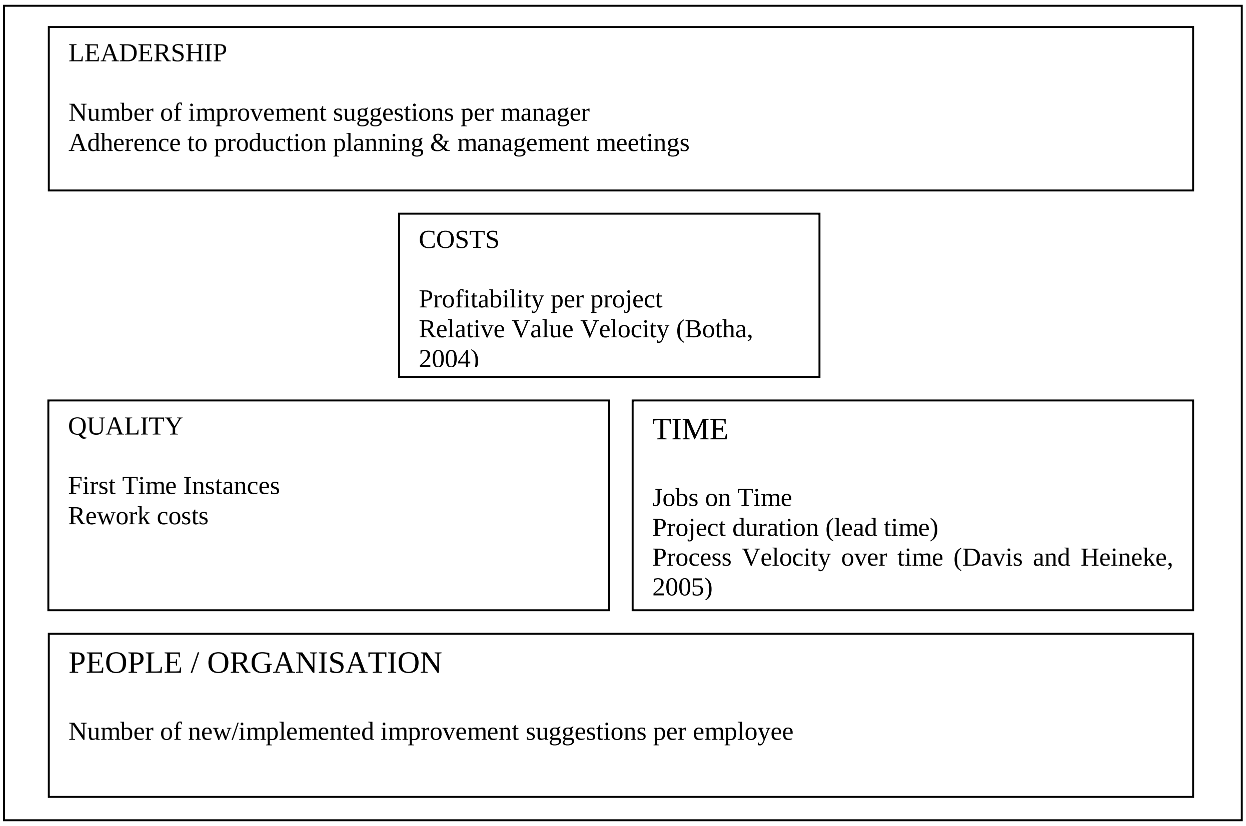

Figure 4: KPI concept consisting of 5 dimensions

In the following the concrete measures covering the dimensions of the KPI concept that are used in the case study are presented (see Figure 4).

Regular management meetings are building the base for reviewing all implementation efforts. The agenda should include for example a review of the KPIs, an evaluation of improvement suggestions and the analysis of problem reports (ideally structured as an A3 report). Those meetings also represent a good opportunity to reflect upon current Lean implementation efforts, e.g. the implementation of 5S methods in a pilot cell and to decide on further measures and steps. Consequently the results and decisions of those meetings represent the drivers respectively the framework for further change measures and thus ensure the sustainability of the changes. One example for the importance of those regular meetings is the implementation of the improvement suggestion system. It is essential that new suggestions are evaluated quickly and correspondent resources (e.g. budget, support by other staff members, etc.) for their implementation are clearly defined and released which is usually done by the management members. Otherwise the time delay between submitting a suggestion by an employee and approving it by the management could be interpreted as low interest of the management. Therefore in the case study the adherence to the planning meetings and to the management meetings are measured in "meetings every x days".

As an additional measure the number of improvement suggestions offered by management members is evaluated (Figure 5).

To monitor the cost dimension the two measures 'profitability per project' and 'relative value velocity' (Botha, 2004) are selected.

The time dimension is covered with the KPIs ‘Jobs on Time’ and the ‘project duration’.
Jobs on Time (JOT): The KPI JOT is the ratio of number of jobs manufactured before the customer-requested shipment date to total number of shipped jobs in a certain time period in percent.
Project duration dependant on turnover categories can be generally divided into two possible measurements: from the sign-off of the customer’s order to the shipment of the finished product (this includes design), or from the point in time a project is released for manufacture to the shipment of the finished product. The latter focuses on the manufacture performance and excludes design issues. In the case of a manufacture-to-order environment with unique products, it turned out to be essential to define product families by categorising the projects according to their turnover (e.g. defining $-bands) and to measure the manufacturing lead time comparing with a target lead time dependent on these categories.

The involvement of the team members are measured by the number of improvement suggestions: An improvement suggestion system encourages all staff members to share their ideas and thus to contribute to continuous improvement projects. Therefore such a system is essential for the infrastructure of a learning organisation and its performance (new suggestions compared with already implemented ones dependant on issue date) could be seen as an indicator for staff motivation and also for the general attitude of the organisation towards problem solving and continuous improvement. Further indicators can be e.g. attendance rate, employee satisfaction (identified by regular surveys), staff turnover rate etc. The absenteeism and turnover of staff members in a SME can be easily perceived in the day-to-day business. Hence a separate official monitoring of those factors did not seem to be reasonable in the case study.
The quality dimension is measured by the KPIs ‘First Time Instances’ and by ‘rework costs’.
First Time Instances (FTI): Indicators often used in mass-production, like Overall Equipment Efficiency (OEE), First Time Through (FTT), Scrap rate, Machine and process capability indices (Cpk or Cp) cannot be applied in an manufacture to order company because of the non availability of repetitive tasks and the uniqueness of the products. The KPI FTI is the ratio of number of shipped jobs without being sent back for rework to total number of shipped jobs in a certain time period in percent. Therefore FTI indicates the perceived quality of the product by the customer.
Rework costs (e.g. caused by non conformal instances): Costs resulting from non conformal instances (manufacturing, design or planning errors) are accumulated and reported every month. These costs include material costs and also labour hours for rework. Thus the rework costs provide information about the internal process performance resp. capability.

Further two Lean performance indicators are selected to monitor the implementation process.
Process velocity over time is defined as total throughput time divided by value added time (Davis and Heineke, 2005). This measurement can be used either to evaluate the flow of materials through the value stream or to measure the individual efficiency of one process revealing the non-value adding time. The process velocity is monitored in every project for those components that are supposed to take the longest manufacturing time and therefore constrain the overall length of the manufacturing lead time. This way of assessing projects in a manufacture-to-order environment is novel and therefore needs further research. Therefore the process velocity (V) can be defined as:

$$V = \frac{T_{Tj}}{\max\left\{\sum_{i=1}^{m} t_{P,ij}\right\}}$$

Relative Value Velocity over time: Botha's (Botha, 2004) Value Velocity tries to measure the rate at which value is added in a company. Therefore value velocity is defined as the ratio of profit before tax of the company (e.g. EBIT, earnings before interest and taxes) and the inventory days.

$$V_V = \frac{EBIT}{inventory\_days} \quad \text{in} \left[\frac{\$}{days}\right]$$

Consequently the Value Velocity in a manufacture-to-order (MTO) environment is defined by the authors as the ratio of profit before tax of a project and its needed lead time (from order of the customer until the shipment date of the product). Because the size of projects (respectively of their turnover) can vary, it proved reasonable to use instead of the absolute amount of profit the percentage of it to the total project budget. This facilitates a comparison of several projects of different sizes. Hence the dimension of this measure is % of profit to project turnover per time unit (e.g. days).

$$V_{V,MTO} = \frac{\frac{EBIT}{Total\_budget}}{leadtime} \quad \text{in} \left[\frac{\%}{days}\right]$$

Application of KPI concept and discussion

In this chapter, some results of the indicators are presented and discussed.

Leadership

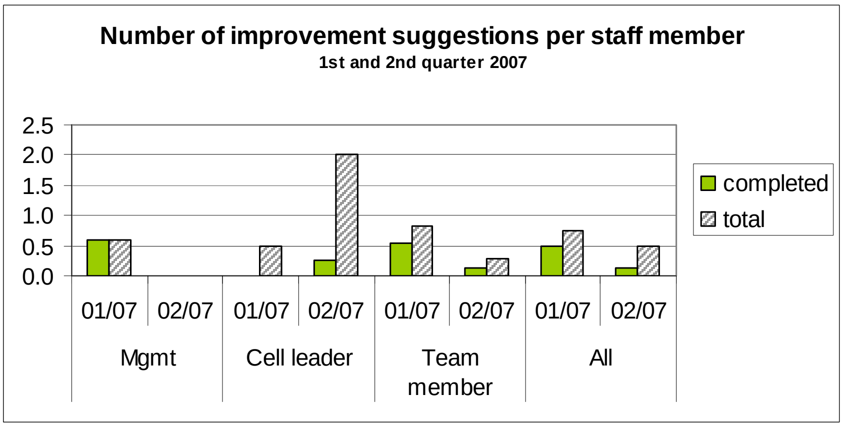

Figure 5: Number of improvement suggestions per staff member, 1st and 2nd quarter 2007

Pil (Pil and MacDuffie, 1999) reveals in a study comparing Japanese automotive transplants with the Big Three, that the transplants make less use of suggestion programmes than the Japanese plants but considerably more than Big Three plants. Indeed, the average worker in a transplant offers roughly four suggestions per year (i.e. roughly one suggestion per quarter), compared to 23 a year for workers at Japanese plants in Japan (i.e. roughly 5.8 suggestions per quarter) and only one suggestion for every four employees in the U.S.-owned plants (i.e. less than 0.1 suggestion per quarter per employee). In comparison to these figures the case study offers 0.8 improvement suggestions in the first quarter and

0.5 improvement suggestions in the second quarter. To evaluate the performance dimension leadership the improvement suggestions are assigned to three hierarchical categories: management member, cell leader, team member (the employees working in one cell belong to one team) (see Figure 5). It is obvious that the management members have a slightly lower participation on the improvement suggestion system, even in the second quarter no improvement suggestion was submitted by any management member. The most active hierarchical organisational level is the one of the cell leaders, which is the only group having an increase of improvement suggestions from the first to the second quarter. Besides it is conspicuous, that in this group the ratio of implemented to open suggestions is worse compared with the category management of team member; one possible explanation in the opinion of the authors is the higher workload respectively the daily responsibilities without having the correspondent hierarchical authority to delegate the implementation of improvement suggestions.
Concerning a sustainable Lean implementation the reason for the decline of the number of improvement suggestion in the second quarter must be found to define correspondent countermeasures. The authors recommend to reduce the measurement frequency to months or even weeks to improve the response time. Besides it showed to be useful to establish targets, e.g. 0.25 implemented improvement suggestions per employee and manager per month. In a company with 50 staff members, this would mean roughly 13 implemented improvement suggestions per month. The KPI and the improvement suggestions themselves must be on the agenda of the management meetings.

Cost, Quality and Time

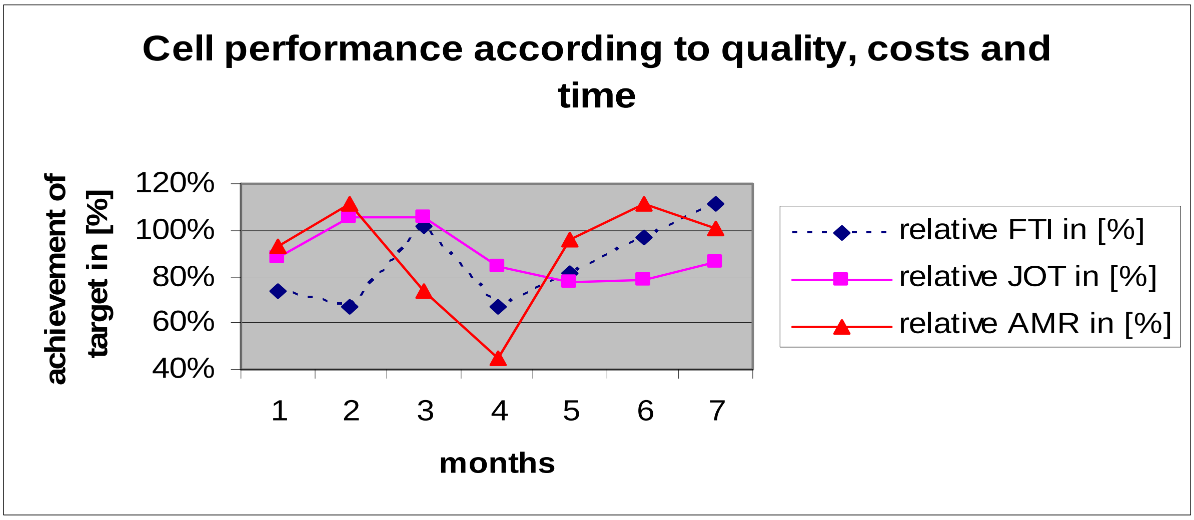

Figure 6: Key performance indicators FTI, JOT and AMR (relative development to the target score from the beginning of the implementation of the KPIs)

In Figure 6 the KPIs FTI, JOT and AMR of one manufacturing cell are shown in relation to the target score. The ratio to the target score was only chosen for confidentiality reasons. It is recommended to use the absolute figures. At Market Rate (AMR) is defined as percentage of projects that achieved the target profitability in a certain time period. This KPI is used in the case study at the cell level and is discussed with the team leaders regularly. The KPIs are generated monthly. Here the authors recommend as well to reduce the measurement interval to one week and to establish a weekly ‘shop floor meeting' where the figures are discussed within the cell. The KPIs are visualised in front of every cell on a board. In the case study the cells need for several manufacturing steps 'external' resources, for example CNC machines that are treated as external suppliers for the cells. Because the KPIs are assessing the whole value stream including those "external" suppliers, some cell leaders complained about the purpose of the KPIs. In their opinion they did not have the authority to control the whole value stream and hence the results of the KPIs did not reflect the real performance of the cell. On the one hand, this still shows the departmental thinking barriers, but on the other hand also pointed out, that regarding the value stream the current organisational layout still needs to be improved. This is one example showing the importance of the thinking in value streams and its consideration during the design of a correspondent KPI concept.

CONCLUSIONS

Measures of a performance measurement system need to fulfil the criteria of validity, reliability, relevance and practicality as mentioned by Hannula (Hannula, 2002).

If the defined KPIs are relevant and practical for the involved staff members, the effort needed for the implementation of such measurement system is acceptable and can be afterwards continuously reduced through standardization. It is essential that performance measurement is not regarded as an independent and discrete management tool or self-contained system. Performance measurement is only one part of a complex regulating system with the lean objective of ongoing improvement as a learning organisation. Hence it is important to integrate KPIs in further mechanisms (e.g. root cause analysis of deviations, standardized problem solving techniques, regular KAIZEN meetings) that support this objective.

The consistency of the measurement results depends mainly on the reliability of the data. Therefore exact rules for information gathering and the sources of information must be defined properly. But in the opinion of the authors, this standardization should be part of successive steps e.g. within the framework of continuous improvement activities. Once the KPIs have proved to be helpful, i.e. valid and relevant to the organisation, the need to improve their reliability and accuracy will also increase.

One prerequisite for that is the active involvement of front-line employees. Every cell or Mini Business Area should be responsible to update those KPIs that are directly connected to their value streams (ownership), for example measuring the lead-time and tracking the spent work hours compared with the budgeted time frame of every project in every cell.

In this paper a KPI concept for a Lean implementation is presented paying special attention to the critical role of the leadership. There hasn't been found any literature integrating the leadership performance dimension into a performance measurement system. Hence further need of research in this area is necessary according to its relevance ((Achanga, 2005), (Collins, 2001)). The need of an early integration of a KPI concept supporting a Lean implementation process mentioned by Ahlstroem (Ahlstroem and Karlsson, 1996) could be confirmed within the case study. KPIs covering the whole value stream support the paradigm change away from individual process thinking and can even provide opportunities for improvement.

Additionally further need for research has been identified in the evaluation of process velocity (according to the definition of M.M. Davis, (Davis and Heineke, 2005)) in a manufacture/engineer-to-order environment, since a generally accepted definition of Work-in-Process in a manufacture-to-order environment does not exist.

ACKNOWLEDGEMENTS

The authors acknowledge the generous support and all insight provided to this study by RPM International Tool and Die, Auckland, New Zealand.

REFERENCES

ACHANGA, P., SHEHAB, E., ROY, R., NELDER, G. (2005) Critical success factors for lean implementation within SMEs. *Journal of Manufacturing Technology Management,* Vol. 17**,** 460-471.

AHLSTROEM, P. & KARLSSON, C. (1996) Change processes towards lean production: The role of the management accounting system. *International Journal of Operations & Production Management,,* Vol. 16**,** 42-56.

BOTHA, W. (2004) Value Velocity or how do I know Lean is working?

BOURNE, K., MILLS, J., WILCOX, M., NEELY, A., PLATTS, K. (2000) Designing, implementing and updating performance measurement system. *International Journal of operations management,* 20**,** 754-771.

CARTON, R. B. (2006) *Measuring organizational performance : metrics for entrepreneurship and strategic management research,* Cheltenham, UK ; Northampton, MA, Edward Elgar.

COLLINS, J. C. (2001) *Good to great : why some companies make the leap - and others don't,* New York, NY, HarperBusiness.

DAVIS, M. M. & HEINEKE, J. (2005) *Operations Management: Integrating manufacturing And services,* The McGraw-Hill/Irwin

EMILIANI, M. L. (1998) Lean behaviors. *Management Decision,* Vol. 36**,** 615-631.

EMILIANI, M. L. (2004) Using value-stream maps to improve leadership. *The Leadership & Organization Development Journal,* Vol. 25**,** 622-645.

FLINCHBAUGH, J. (2006) Lean Manufacturing: Moldmaking through the Lean lens.

FLINCHBAUGH, J. & CARLINO, A. (2006) *The hitchhiker's guide to lean: Lessons from the road,* Society of Manufacturing Engineers.

GREEN, L. (2004) Implementation of Lean manufacturing in a small sized company. California State University Dominguez Hills.

HANNULA, M. (2002) Total productivity measurement based on partial productivity ratios. *International Journal of production economics,* Vol. 78**,** 57-67.

HINES, P., HOLWEG, M. & RICH, N. (2004) Learning to evolve. A review of contempory lean thinking. *International Journal of Operations & Production Management,* Vol. 24**,** 994-1011.

HIROMOTO, T. (1988) Another hidden edge-Japanese management accounting. *Harvard Business Review.*

HUDSON, M., SMART, A. & BOURNE, M. (2001) Theory and practice in SME performance measurement systems. *International Journal of Operations and Production Management,* Vol. 21**,** 1096-1115.

KUTUCUOGLU, K. Y., HAMALI, J., IRANI, Z., SHARP, J.M. (2001) A framework for managing maintenance using performance measurement systems. *International Journal of operations and production management,* Vol. 21**,** 173-194.

LEAN ENTERPRISE INSTITUTE (2007) New survey: Middle managers are biggest obstacle to Lean enterprise.

LEVINSON, W. A. & RERICK, R. A. (2002) *Lean enterprise: A synergistic approach to minimizing waste,* New York, ASQ Quality Press.

LIKER, J. K. (2003) *The Toyota Way,* New York, McGraw-Hill.

LIKER, J. K. & MEIER, D. (2006) *The Toyota Way Fieldbook: A practical guide for implementing Toyota's 4Ps,* New York, McGraw-Hill Companies, Inc.

LIND, J. (2001) Control in world class manufacturing - A longitudinal case study. *Management Accounting Research,* Vol. 12**,** 41-74.

MASKELL, B. H. (1991) *Performance Measurement for World Class Manufacturing,* Cambridge, UK, Productivity Press.

MASKELL, B. H. (2004) *Practical lean accounting : a proven system for measuring and managing the lean enterprise,* New York, NY, Productivity Press.

MINISTRY OF ECONOMIC DEVELOPMENT (2006) SMEs in New Zealand: Structure and dynamics.

NAKAJIMA, Y. (1994) *Toyota production system: An integrated approach to just-in-time. 2nd edition. ,* Chapman hall publishing.

NEELY, A., MILLLS, J., PLATTS, K., GREGORY, M. AND RICHARDS, H. (1994) Mapping measures and activities: A practical tool for assessing measurement association systems. *First international conference of the European operations management association.* Cambridge (UK).

NZTE (NEW ZEALAND TRADE AND ENTERPRISE) (2006) Specialised manufacturing: Sector engagement strategy 2006-07.

PIL, F. K. & MACDUFFIE, J. P. (1999) What makes transplants thrive: Managing the transfer of "Best Practice" at Japanese auto plants in North America. *Journal of World Business,* Vol. 34**,** 372-391.

SENGE, P. (1990) *The Fifth Discipline,* New York, Currency/Doubleday.

SHINKLE, G., GOODING, R. & SMITH, M. (2004) *Transforming strategy into success: How to implement a Lean management system.,* New York, Productivity Press.

SOBEK, D. K. (?) A3 Reports: Tool for Process Improvement. *Mechanical and Industrial Engineering.* Bozeman, Montana State University.

WOMACK, J. & JONES, D. (1996) *Lean Thinking: Banish waste and create wealth in your corporation,* New York, Simon & Schuster.

WOMACK, J. P., JONES, D. T. & ROOS, D. (1990) *The machine that changed the world,* New York, Harper-Collins.