Human Factors in Production Planning and Control

How to Change Potential Stumbling Blocks into Reliable Actors

Hans-Peter Wiendahl, Gregor von Cieminski, Carsten Begemann and Rouven Nickel
University of Hannover, Institute of Production Systems and Logistics (IFA), Callinstrasse 36, D-30161 Hannover, Germany.
Email: {cieminski, wiendahl}@ifa.uni-hannover.de

Abstract: The influence of human actors on production planning and control (PPC) systems is significant. This paper describes a number of ways, in which human interaction with PPC systems affects the logistic performance of production. It demonstrates how human decisions and behaviour can act as stumbling blocks for PPC. Logistic models and PPC procedures that remove these stumbling blocks are presented. Moreover, the paper proposes the concept of 3-Sigma PPC as a holistic approach to PPC. 3-Sigma PPC recognises the influence of human factors on PPC and incorporates methods that improve human decision-making so that a better logistic performance can be achieved.

Key words: Production planning and control, Disturbances, Human factors, 3-Sigma PPC

1. CLASSICAL STUMBLING BLOCKS OF PPC

So far, progress in the field of production planning and control (PPC) has not been able to change the fact that lead times and inventory levels remain not fully controllable in many manufacturing enterprises and thus hinder compliance with delivery due dates. Relying on the continuing advances in information technology, companies often attempt to solve these problems solely with new PPC software systems. However, the actual causes of the shortcomings of production logistics do not normally reside in inadequate software only. Numerous studies of the Institute of Production Systems and Logistics (IFA) and the Institute of Manufacturing Engineering and Automation (IPA) show that the consequences of a wide range of economic, organisational and behavioural factors are the true stumbling blocks of PPC

(WIENDAHL et al. 2003; WIENDAHL 2003). Figure 1 provides an overview of these factors that originate from within production enterprises as well as from the market environment.

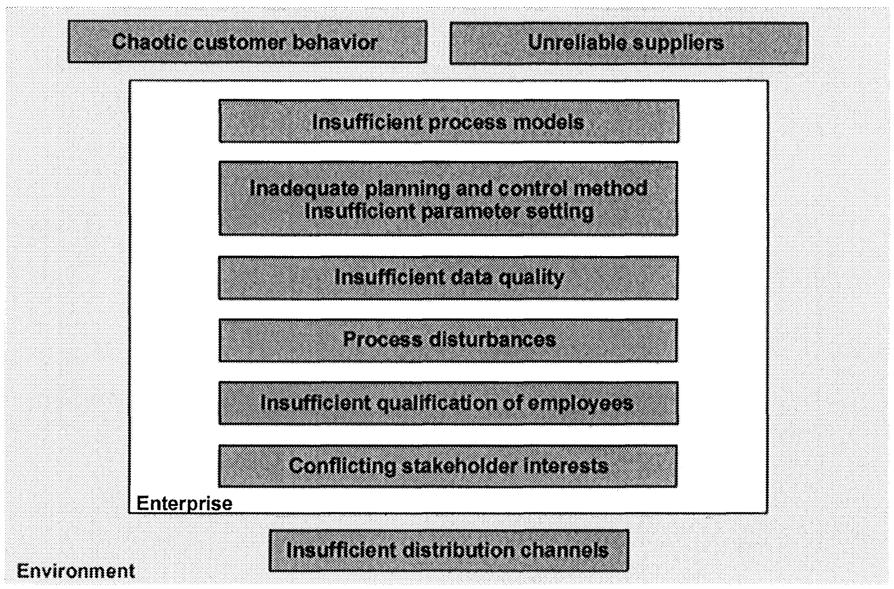

Figure 1. Causes of the classical stumbling blocks of PPC

In the external environment manufacturing enterprises can only control certain factors – e. g. their distribution channels – while other factors remain outside their direct control – e. g. the behaviour of their customers or suppliers. Due to this lack of control, manufacturers are often forced to accept the external factors as stumbling blocks of PPC. Internally however, the enterprises are required to resolve a range of problems that prevent high levels of logistic performance (see Figure 1). These range from insufficient process models and inadequate PPC methods as well as insufficient parameter settings, through insufficient data quality and technical process disturbances, to insufficient qualification of production planners or shop floor operators and conflicting PPC stakeholder interests. The majority of these problems have a strong connection to the activities of human staff working in manufacturing enterprises. Human operators are responsible for carrying out the procedures prescribed by the PPC control methods. They have to ensure high data quality within the PPC system. The impact of their level of qualification or the extent to which they pursue their own interests is self-evident. Hence, human actors have a special significance for the logistic performance of PPC systems, which is the subject of this paper.

The paper uses an overview of the PPC control cycle to generally introduce human influences on PPC systems. It provides detailed descriptions of the specific human stumbling blocks related to PPC systems, the level of qualification of employees and the stakeholder interests of PPC as well as measures to remove them. Furthermore, section six presents the 3-Sigma PPC approach that addresses human aspects of PPC as a key feature for improving the logistic performance of PPC systems.

2. HUMAN INFLUENCES ON PPC SYSTEMS

Employees in production planning departments, operators on the shop floor and all other members of staff who participate in PPC activities are actors of PPC systems. The main responsibility of PPC actors is decision-making. Decisions made by the actors affect the logistic performance of production systems in two ways: If the actors take correct decisions, the PPC system is effectively controlled to achieve the logistic performance objectives even if unplanned disturbances occur. Mistakes or oversights in the decisions made by actors run contrary to the logistic performance objectives. The actors either succeed to guarantee high levels of logistic quality by stabilizing the production process. Conversely, they may reduce logistic performance levels by becoming a cause for disturbances themselves. Figure 2 shows the stages of the PPC control cycle. As the actors are involved in decision-making in every step of this cycle it is useful for highlighting their influence on the logistic performance of PPC.

The first step of the cycle is the setting of strategic logistic objectives and corresponding performance targets. In the next step, planning activities establish the production program and the material and capacity plans. The purchasing, production and distribution functions execute the plan. During fulfilment, production and machine data acquisition systems record data that illustrate the actual throughput of orders through production. Performance measurement systems calculate and analyse the logistic performance of the production system and feed the analysis results back to the planning department. On the basis of the performance data, decisions for the following control cycle are taken.

In addition, Figure 2 indicates that disturbances can lead to deviations of the actual events in production from production plans at several points within the PPC control cycle (WIENDAHL 2003). In these cases, the task of the PPC actors is to either rule out disturbances from the outset by making appropriate control decisions. Alternatively, if disturbances do occur, the actors have to react to them, correct them if possible and take all actions necessary to maintain the fulfilment of the logistic objectives.

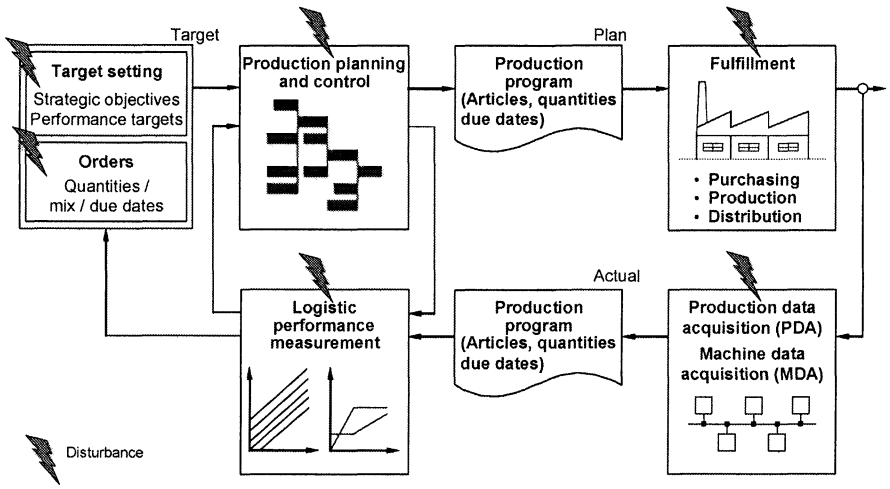

Figure 2. Possible sources of disturbances in the PPC control cycle

Often, target setting is ineffective because production planners try to fulfil conflicting logistic objectives simultaneously. During the execution of production plans, unplanned events like machine breakdowns disturb the original framework of the plans. This requires measures that seek to limit the effects of the disturbances on the logistic performance. A detailed understanding of the logistic effects of certain kinds of disturbances to production processes is required of production planners and operators to rectify the situation. Production and machine data acquisition systems and logistic performance measurement systems depend on accurate data to provide a true view of the actual logistic state of a production system. As these functions are not normally fully automated, the actors who feed data into the systems or who oversee performance analyses have to ensure data accuracy. They have to be aware that incorrect production data distort the actual logistic performance. This can lead to decisions that are based on wrong assumptions about the status of orders.

The three most significant factors that emerge as possible human stumbling blocks of PPC from this discussion are as follows:

1. the PPC systems, which often do not facilitate unambiguous human decision-making in order to achieve specific logistic objectives,
2. the lack of qualification of employees, which prevents actors from understanding the effects of their decisions on PPC systems,
3. the stakeholder interests, which serve individual, localised purposes rather than attempting to achieve the agreed logistic performance targets of an entire production system.

2.1 Stumbling Block: PPC Systems

The planning and control systems applied often represent a stumbling block of PPC. The best-known PPC system is the MRP II (Manufacturing Resource Planning) approach (WIGHT 1984). It incorporates the functions of business planning, production program planning, material requirements planning, scheduling and production control and contains precise procedures for all of these as well as for their connections. MRP II relies on centralised planning procedures that apply the output rate as their control variable and therefore emphasise the logistic objective of achieving high resource utilisation. Although MRP II is still employed in many manufacturing companies and also forms the basis of many PPC software systems (VOLLMANN et al. 1997), the inflexibility of its procedures and the resulting inability to adjust to a dynamically changing environment mean that the system is reaching the limits of its applicability.

The current requirements of manufacturing enterprises render the application of new PPC systems necessary, which are able to adapt to the changing boundary conditions. On the one hand, the systems have to be able to cope with the increasing variety of product variants and have to be applicable to manufacturing systems with highly complex material flows. On the other hand, modern PPC systems must consider the known interrelationships between logistic objectives and control variables (see section 2.2). For this purpose it is desirable that the execution procedures integrate the skills of the machine operators by decentralising as many PPC functions as possible (see Figure 3).

PPC systems like the Decentralised WIP-oriented (DeWIP) control empower the operators of every production work system to rationally pursue its specific logistic performance objectives (LÖDDING 2000). Figure 3 shows the DeWIP control procedure. From a human factors perspective, the most important characteristic of DeWIP are its short control loops. Operators have the unambiguous logistic objective of controlling the work-in-process (WIP) level at their respective work systems. They use direct communication with their colleagues to achieve this target: All operators of the work systems in Figure 3 continuously monitor current and future WIP levels. When an order is released into production from the central production program, work system 1 has to request authorisation to start processing from work system 2. Work system 2 only gives this authorisation if its current WIP level does not exceed capacity. The same logic applies to all other work systems within the production department. The shop floor has the permission to overrule the production program established by the centralised PPC system if the current status of production requires this. Excess WIP levels, which overload manufacturing capacities and increase throughput times, are thus avoided.

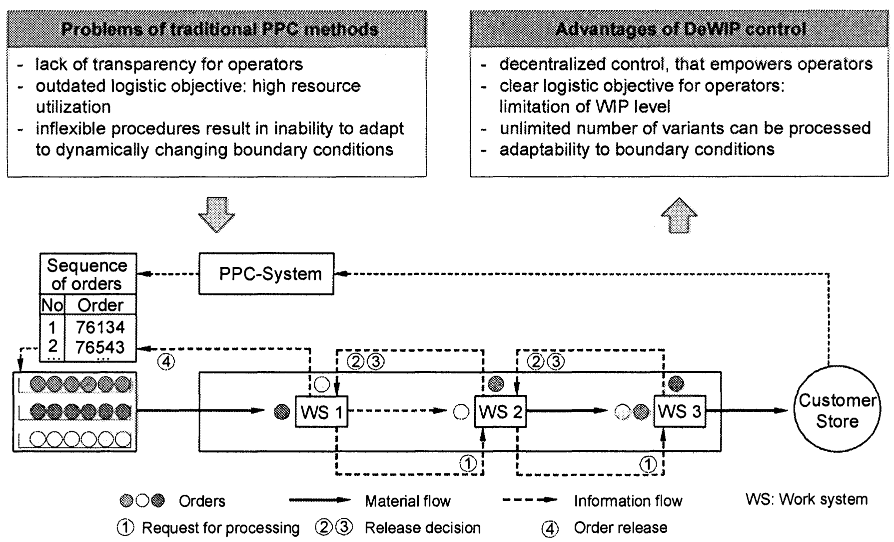

Figure 3. Empowering operators through decentralised WIP control (adapted from LÖDDING 2000)

2.2 Stumbling Block: Qualification of Employees

The level of qualification of the production staff represents a further stumbling block for PPC. In practice, both the employees that are directly involved in the production process as well as the employees that carry out production planning and control tasks may act or react irrationally due to a lack of understanding of dynamic logistic processes. Attempting to achieve a local optimum, they concentrate on the apparently most urgent problem.

A typical behavioural model, which is caused by an insufficient understanding of the planning process, is the vicious circle of errors of PPC (MATHER, PLOSSL 1978) that is shown in Figure 4. Production planners frequently ascribe a poor schedule reliability to short planned throughput times. Consequently, they increase the planned values. Thus, they release production orders earlier and increase the WIP levels in production. Queuing times in production rise and the schedule reliability deteriorates further. Only through the expediting of express orders can the production department manage to deliver orders on time. The employees are unaware that their decisions result in this spiral of events that affect the quality of PPC.

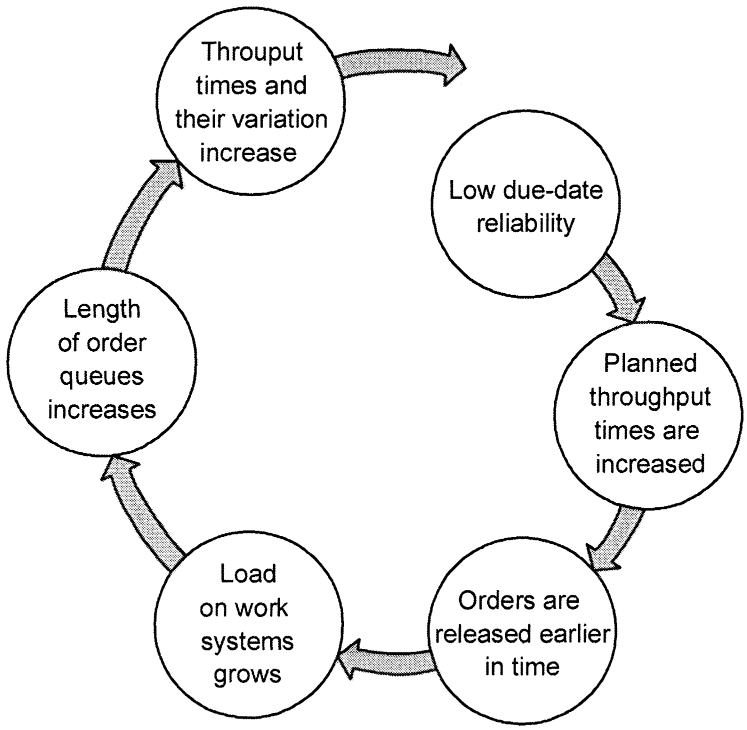

Figure 4. Vicious circle of errors of PPC
(adapted from MATHER, PLOSSL 1978)

Consistent logistic models of production processes can help to break the vicious circle of errors of PPC. The models explain the causal interrelationships between PPC control variables and logistic performance measures. For example, the models can be applied to make human actors aware of the rise in the workload on production resulting from an increase of the planned throughput times. Examples of such logistic models are the funnel model and the throughput diagram (WIENDAHL 1994) as well as the Logistic Operating Curves (NYHUIS, WIENDAHL 2003).

The funnel model is an analogy for the events at a work system during the processing of manufacturing orders. It forms the basis for the throughput diagram that visualises the events and enables the calculation of logistic performance measures from production feedback data. In combination, the two models show the exact consequences of PPC measures on the logistic behaviour of a work system over time.

A phenomenon that can frequently be observed in practice is the arbitrariness with which operators report production feedback data. Industrial studies carried out by IFA show that operators accumulate a WIP level of completed orders at their work systems over the course of a working week. Only at the end of the week or before holidays are these "buffers" dissolved: The operators report the orders as completed and thus release them to the succeeding work system. The WIP buffers serve as an insurance against reductions in output rate caused by possible process disturbances. This behaviour distorts the production feedback data, which can lead to the wrong control decisions being taken. It also increases the work system WIP levels and thus causes increases in the variation of throughput times. The throughput diagram visualises the negative effects of such inaccuracies in the feedback data. The diagram can be used to educate human actors about the consequences of their actions.

On the other hand, the Logistic Operating Curves describe the behaviour of the logistic performance measures output rate, throughput time and delivery reliability depending on variations in the WIP level of production resources. Therefore, the operating curves are a means to identify production planning and control measures that are adequate to achieve specific logistic objectives. They also highlight the conflicts between different objectives. The more human actors are aware of these interrelationships, the better they can contribute to good logistic performance by taking appropriate decisions and setting realistic performance targets. Reiterations of the vicious circle of errors are thus avoided.

2.3 Stumbling Block: Stakeholder Interests

It is essential to bear in mind that natural individual interests of different groups of staff – the PPC stakeholders – coexist besides the formal logistic performance objectives of a PPC system (schedule reliability, throughput time, WIP level, resource utilisation). Commonly, manufacturing companies do not officially acknowledge the existence or nature of these interests. The latter depends on the roles that the stakeholders fulfil in the context of PPC or within the company. Clearly, different groups of staff pursue distinct objectives, which results in a complex structure of individual, possibly conflicting, stakeholder interests and their motivation (MASLOW 1987).

Machine operators constitute a typical group of PPC stakeholders. The main objectives of this group are to protect their workplace and to keep the processing of production orders stable. As has been pointed out before, the operators tend to "hoard" production orders for periods of low resource loading and thus create safety WIP levels. In addition, they arrange the processing sequence of orders in a way that fits their daily and weekly work rhythm. Figure 5 depicts a graphic example of this behaviour that IFA found during a study in a manufacturing enterprise. The company had configured its pull control system for low WIP levels: Six kanban cards were meant to ensure lean production (see Figure 5a). Low production WIP levels caused significant idle times at the work systems in the production department. In order to reverse this situation and to suggest to management that they were busy most of the time, the operators artificially increased the WIP level by adding copies of the original kanban cards to the control cycle (see Figure 5b).

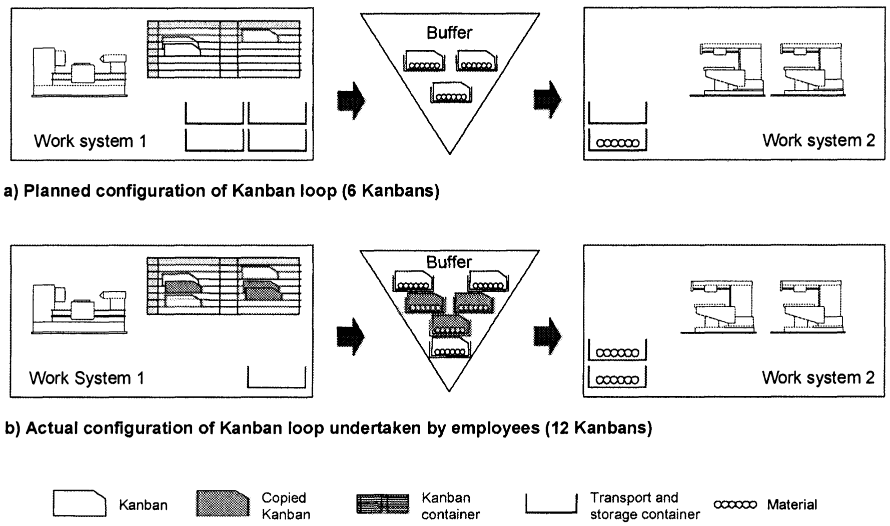

Figure 5. Consequences of the fear of utilisation losses in a Kanban system

A second important group of PPC stakeholders are the expeditors. Their objective is to ensure the on-time fulfilment of priority orders. For this purpose, expeditors "chase" production orders past the production work systems. If successful, they are often regarded as the "heroes of production who make the impossible possible".

Neither the machine operators nor the expeditors have a genuine desire for a PPC system whose procedures "automatically" fulfil the formal logistic objectives in the interest of the company and its customers. The reasons for this are identical in both cases: Both actors fear for their existence. While the fears of the machine operators are mostly unfounded and can frequently be put down to a lack of qualification or an inadequate compensation system, expeditors have a better understanding of the dynamic logistic processes and are aware that more effective PPC systems would render their function superfluous. Stakeholder interests are also caused by a lack of qualification in production logistics. In this context, it is especially important to create an awareness amongst the employees for the consequences of their actions for themselves and their colleagues who are affected. In order to minimise the effects of these personal interests the wage and incentive system has to reward conformance to the overall objectives of the production system. Thus, customer orientation, high logistic performance levels and quality and the conformance of decisions to objectives of the PPC system should all be rewarded.

3. THE 3-SIGMA APPROACH TO PPC

The 3-Sigma PPC approach is based on a holistic view of the impact of the three features human actors, organisation and logistic models on PPC systems (see Figure 6; WIENDAHL et al. 2003). 3-Sigma PPC represents an important extension of traditional PPC methodologies that almost exclusively concentrated on the feature of the logistic models. The concept aims to integrate the solutions to the human stumbling blocks described above with elements from the other features in a single coherent framework for PPC.

The vision of 3-Sigma PPC is to establish PPC systems as quality management systems for the logistic performance of production systems. The concepts of process capability and reliability are transferred to the logistics context and logistic quality becomes measurable in terms of sigma (σ). It stands for the standard deviation, a statistical measure of the distribution of a characteristic around a mean value. For a quality characteristic with a normal distribution and a permissible tolerance equal to 3 Sigma, 99.73 % of all values have to lie within the tolerance range (EVANS, LINDSAY 2001). As its name suggests, 3-Sigma PPC transfers this quality requirement to PPC systems. This means that PPC procedures have to control a production system in such a way that its logistic objectives are met within the specified tolerance in 99.73 % of all cases.

The examples above illustrate the influence of actors within 3-Sigma PPC. For this PPC approach it is essential that all actors have the necessary qualification in production logistics. The actors need to be able to understand the structure of the production-logistic models that the PPC systems use. They have to be aware of the logistic performance objectives and the variables with which they can influence them. Also, they need to know and understand the interrelationships between both, i.e. what consequence the modification of a control variable has on the logistic performance. Besides this qualification, the actors also have to have the competence to apply the PPC system, methods and algorithms, to carry out their task of maintaining the logistic performance levels.

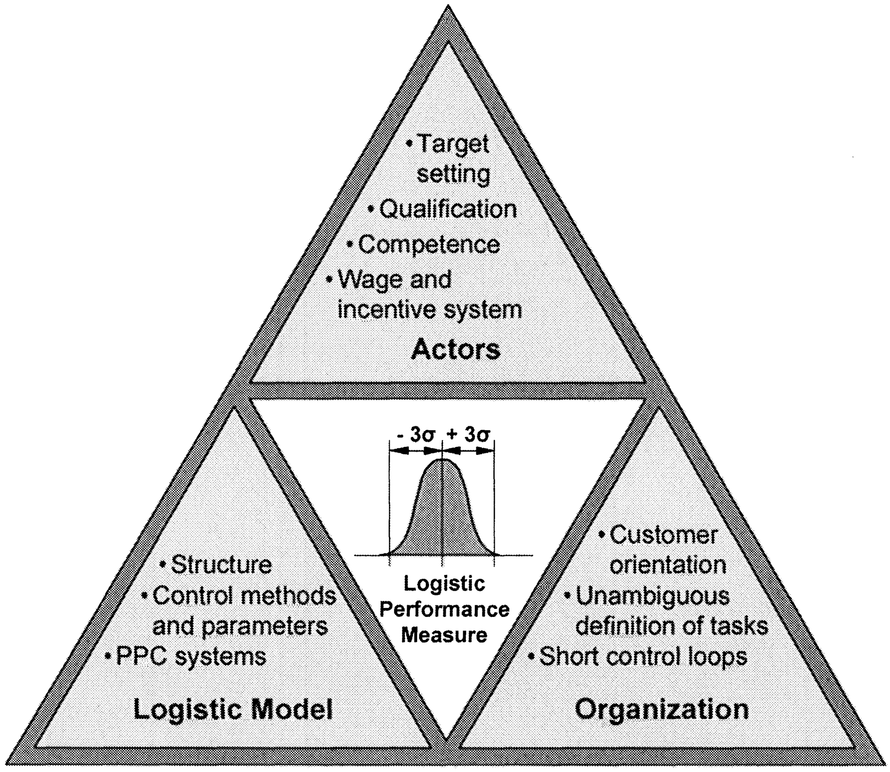

Figure 6. Features of the 3-sigma PPC approach (according to WIENDAHL et al. 2003, p. 91)

Ideally, actors at all levels of the PPC system – production planners and shop floor operators alike – have this qualification and competence. The more the qualification to interpret interdependencies between performance measures and control measures can be decentralised, the more action for performance improvements can be taken rapidly and directly. This applies to all stages in the PPC control cycle in Figure 2. Qualification facilitates the correct interpretation of production-logistic models for appropriate and consistent target-setting. This is followed by the definition of feasible production plans, for which the likelihood of changes occurring is reduced. The group of actors is enabled to rapidly react to disturbances in the purchasing, production or distribution functions so that the effects on logistic performance are minimised. The actors are also aware that for a realistic assessment of the actual logistic situation in a production system, feedback data have to be provided accurately and as early as possible. Moreover, the performance measurements taken from the shop floor should conform to the production-logistic models in the same way as the information that is fed back into the system for control purposes.

4. CONCLUSIONS

The paper introduced the classical stumbling blocks of PPC and emphasised the involvement of human actors in causing and affecting them. Using the PPC control cycle as a framework, the paper demonstrated how decisions taken by human actors can lead to disturbances and adverse effects on logistic performance. The human aspects of three particular stumbling blocks – PPC systems, qualification of employees and stakeholder interests – were detailed further. Here, the paper provided examples from industrial practices as well approaches to remove the stumbling blocks.

The 3-Sigma PPC concept integrates these individual solutions in a general approach for achieving high levels of logistic performance and quality. 3-Sigma PPC combines the human aspects considered in this paper with two further features of PPC, logistic models and organisation. IFA intends to continually elaborate the 3-Sigma PPC approach by developing new production management methods that improve all features of 3-Sigma PPC. Specifically, the role of human actors in PPC decision-making is to be further explored in cooperation with experts from the field of ergonomics and organisational psychology.

REFERENCES

EVANS, James R.; LINDSAY, William M.:
The Management and Control of Quality.
St. Paul, MN: West Publishing, 5th ed., 2001.

LÖDDING, H.:
Decentralized WIP-oriented Manufacturing Control.
In: The manufacturing system in its human context - a tool to extend the global welfare.
Stockholm: CIRP College International pour l'Etude Scientifique des Techniques de Production Mecanique, 2000.
(Proceedings of 33rd CIRP International Seminar on Manufacturing Systems)

MATHER, H.; PLOSSL, G.:
Priority fixation versus throughput planning.
In: Production and Inventory Management,
Washington, DC, 19(1978)3, pp. 82-95.

MASLOW, Abraham H.:
Motivation and Personality.
Boston, MA; Addison-Wesley, 3rd ed., 1987.

NYHUIS, Peter; WIENDAHL, Hans-Peter:
Logistische Kennlinien: Grundlagen, Werkzeuge und Anwendungen..
Berlin et al.: Springer Verlag, 2nd ed., 2003.
VOLLMANN, Thomas E.; BERRY, William L.; WHYBARK, David C.:
Manufacturing Planning and Control Systems.
New York, NY: McGraw-Hill, 4th ed., 1997.
WIENDAHL, Hans-Hermann:
Marktanforderungen verstehen, Stolpersteine erkennen.
In: Proceedings of Management Circle Seminar "Flexible atmende Produktion: Auftragsschwankungen in den Griff bekommen".
Eschborn: Management Circle, 2003.
WIENDAHL, Hans-Peter:
Load-oriented Manufacturing Control.
Berlin et al.: Springer, 1994.
WIENDAHL, Hans-Peter; BEGEMANN, Carsten; NICKEL, Rouven:
Die klassischen Stolpersteine der PPS und der Lösungsansatz 3-Sigma-PPS.
In: Expertensystem Logistik
Eds.: Wiendahl, Hans-Peter; Luczak, Holger.
Berlin et al.: Springer Verlag, 2003.
WIENDAHL, Hans-Peter; BEGEMANN, Carsten; NICKEL, Rouven; CIEMINSKI, Gregor von:
Human Factors as Stumbling Blocks of PPC.
In: Current Trends in Production Management.
Eds.: ZÜLCH, Gert; STOWASSER, Sascha; JAGDEV, Harinder S.
Aachen: Shaker Verlag, 2003, pp. 87-93.
(esim – European Series in Industrial Management, Volume 6)
WIGHT, Oliver W.:
Manufacturing Resource Planning: MRP II.
Indianapolis, IN: John Wiley & Sons, Revised edition, 1984.