To appear in the *International Journal of Production Research*
Vol. 00, No. 00, February 2013, 1–12

Influence of JIT goals on utilization for a hierarchical decision model

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(*v4.0 released February 2013*)

Finding the optimal capacity for the machinery is a standard goal in accounting and finance. Opposing goals on each hierarchical planning level lead to different utilization levels. In this article, a utilization concept is developed in which the JIT goals are taken into account. The concept shows that JIT capability enables the production system to reduce the excess capacity by disinvestment or to increase sales without additional investment.

It is shown that low utilization at the short-term level is positively correlated to JIT-intensive practices. Consequently, low utilization is positively correlated with higher profit. Furthermore, there is no reason to maximize the short-term machine utilization, other than to sell more machine capacity in the sense of selling more products or producing for external companies.

Keywords: hierarchical decision model, utilization, JIT, seven zeros, excess capacity

1. Introduction

Many industries are facing strong global competition where product life cycles are shortened, time to market decreases and customers require fast deliveries of a variety of products of an appropriate quality. Therefore it is absolutely necessary that a company ensures that the right product of the right quality is available to the customer in the right quantity at the right time.

Many companies have recently implemented a hierarchical production planning approach, which is demonstrated by the interests of recent research in the integrated investigation of two or more planning levels (Rafiei, Rabbani, and Alimardani 2013; Chakrabortty and Hasin 2013; Jansen, Kok, and Fransoo 2013). The hierarchical production planning approach (Hax and Meal 1975; Meal 1984; Schneeweiß 2003; Hopp and Spearman 2008) stipulates that first a strategic decision on capacity investment (for instance number and type of machines) is made and subsequently the human resources planning (for instance number of leasing workers or shift model) is performed. Finally, on an operational level, the production controlling and execution (for instance applied lot size, job release) is conducted. This leads to the following three planning levels:

(1) Long term (capacity investment decisions)
(2) Medium term (change of the shift model, introducing overtime, number of leasing workers, time frames for preventive maintenance ...)
(3) Short term (operational level)

Rafiei, Rabbani, and Alimardani (2013) investigates the medium-term and short-term production planning level in a hierarchical production planning approach. They developed an MTO/MTS hybrid production planning strategy, which is modelled as a meta-heuristic algorithm. Chakrabortty and Hasin (2013) observed for a multi-product, multi-period the aggregated production planning with forecasted demand, related operating costs and capacity. Their approach minimizes total

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costs including inventory levels, labor levels, overtime, subcontracting and back-ordering levels, and labour, machine and warehouse capacity. Jansen, Kok, and Fransoo (2013) investigated in hierarchical production planning setting the non-linear relationship between WIP of a production unit and lead time. Therefore, they presented a two step lead time anticipation procedure where an LP is solved without including the available production capacity. A local smoothing heuristics is applied which tracks the stochastic workload in the planning horizon.

The classical long term objective is to minimize the capacity invested or equivalently to maximize the utilization. In the medium term, capacity adjustments are made resulting from demand fluctuations. In the short term view, minimizing the utilization means to produce efficiently because the losses according to the seven zero philosophy are avoided. In the following literature, opposing goals on each hierarchical planning level are reviewed.

According to Hopp and Spearman (2008) utilization is controversial because high utilization leads to low costs per unit but low utilization allows high sales. Bradley and Glynn (2002) developed an analytic model for a single machine and single product system which describes the optimal long-term balance between capacity and inventory. They clearly show that optimal inventory policy varies with capacity investment. One concrete result of their work is that higher capacity invested (this means lower utilization) allows less inventory. Bradley and Glynn (2002) describe how inventory should be optimally substituted for capacity to minimize costs as the capacity level varies. van Mieghem and Rudi (2002) addressed this issue for a more general situation and gained similar results. Obviously there is a trade off between capital invested in capacity and costs of the employed capital in inventories. Carrillo and Gaimon (2000) investigated the manufacturing performance through process changes and knowledge creation with an optimal control model. They argued that process changes may lead to long-term increase in effective capacity but during implementation typically reduce short-term capacity. After reviewing relevant literature it became clear that on each hierarchical level, utilization is treated differently.

Various empirical studies examine the influence of JIT activities on companies' performance. The results of Sim and Killough (1998) provides empirical evidence that performance gains from synergies of JIT activities result from combining JIT activities with performances goals. White, Pearson, and Wilson (1999) identified by a survey of US manufacturing companies 10 JIT activities that are appropriate for implementation. Changes in performance depend on the degree of JIT implementation and the company size. White and Pearson (2001) proposed how JIT activities can be implemented in to the decision making process of manufacturing companies. According to the empirical study among Canadian automotive parts manufacturing industry, Callen, Morel, and Fader (2005) show that JIT intensive plants have more capacity waste than other plants but they generate more profits. Inman et al. (2011) observed with their structural equation model the influence of JIT activities on firm's manufacturing agility. They argued that if JIT activities in the manufacturing processes are already implemented in a company, then an increased supplier/customer integration could show a greater impact on agility than JIT activities alone. Obermaier and Donhauser (2012) analysed the financial performance of companies as a function of inventory holding in their empirical study. They identified a positive relationship between inventory holding and financial performance. Accordingly, those companies with highest inventory show best financial performance and vice versa. Their findings show that the core principle of JIT, avoiding waste and therefore inventory, is not always a disadvantage. Already in 1983 Edwards (1983) has introduced the seven zeros - zero defects, zero lot-size, zero set-ups, zero breakdowns, zero handling, zero lead-time, zero surging - as JIT goals.

The reviewed literature lacks of an investigation on firms' performance of JIT activities on each hierarchical level since it is known that opposing goals exist on each hierarchical level. In our article, the seven zeros as JIT goals are linked with the performance metrics utilization. This enables an analytical discussion of JIT activities on each hierarchical planning level and introducing a JIT intensity key figure.

After the introduction, in chapter 2 the seven zeros as JIT goals are discussed. This is followed by the model description where utilization is connected to the seven zeros in chapter 3. Before concluding the article, the relationship of utilization as performance indicator for JIT activities is discussed on each hierarchical planning level in chapter 4 and a managerial insight is presented.

2. Seven zeros - JIT goals

Just-in-Time (JIT) is a philosophy with the primary goal of continuously reducing all forms of waste (Sugimori et al. 1977; Ohno 1988). Suzaki (1987) identified waiting time, transportation, processing, inventory and motion as possible forms of waste. According to Brown and Mitchell (1991) there are two major forms of waste: high inventories and unnecessary delays. Obermaier and Donhauser (2012) claimed that inventory is not always a disadvantage because they identified in their empirical study a positive correlation between inventory holding and company performance. Edwards (1983) introduced the seven zeros as JIT goals, which have to be achieved to eliminate all forms of waste, especially inventories. The term zero should express that these figures should be continuously minimized. "Zero"indicates a philosophy to avoid waste and does not imply that e.g. zero lot size is required. The seven zeros are discussed in more detail below.

2.1 *Zero defects*

No scrap losses and rework are acceptable. One method to approach zero defects is implementing Total Quality Management (TQM). The aim of TQM is to continuously improve and sustain the quality of products and processes. In addition TQM has a strong customer as well as process orientation. Rehder (1989) stated that JIT and TQM are mutually supportive. Flynn, Sakakibara, and Schroeder (1995) showed empirically that TQM practices improve just-in-time performance and JIT activities have a positive effect on quality performance. According to Deming (2000) TQM also reduces fluctuations in all system components. This is considered to be a prerequisite for introducing JIT.

2.2 *Zero lot size*

The production lot sizes should be equal to the customer order quantity. There should be no queuing time because of production lots greater than the customer orders. Short set up times (see the JIT goal zero set up) are the main prerequisite of small production lots, permitting a good match between production rate and customer demand (Kumar 2010). In a very highly customized environment, this means the production lot size is equal to the customer lot size. Furthermore, small lot sizes increase production flexibility. In addition, it may be useful to have smaller transport batches than production lots to ensure a smoother material flow.

2.3 *Zero set ups*

Reducing set up times is an ongoing process according to Shingo (1985). The target is that no changeovers are necessary or at least the set up times are vanishing. Thus, small lot sizes are only possible if the set up times are very short. Finch (1986) addressed a variety of techniques to reduce and simplify set ups. One key concept is to distinguish between internal and external set up. Internal set up time causes an interruption of the production process while the external set up can be done parallel to the production. Single Minute Exchange of Die (SMED) is one of the most widely known methods to reduce the set up time (Shingo 1985). Combining zero lot size and zero set ups means that the total time used for changeovers decreases even though the number of set ups increases.

2.4 *Zero breakdowns*

No machine failures are acceptable. Zero breakdowns means that there is no idle time caused by machine or tool failure. Total Productive Maintenance (TPM), see for instance Nakajima (1988), is a method to maximize equipment effectiveness throughout its entire life. Many authors, for instance Schonberger (1986) with his concept of world class manufacturing, stated the importance of simultaneously introducing JIT, TQM and preventive maintenance practices. Cua, McKone, and Schroeder (2001) conducted a survey of TQM, JIT and TPM practices and their overlaps. In addition, their study clearly demonstrates the importance of joint implementation of JIT, TQM and TPM.

2.5 *Zero handling*

Unnecessary movement of the material is not acceptable. The items go directly from one workstation to the next. The goal zero handling yields short processing times as well as short transport times and no queuing time between two workstations.

2.6 *Zero lead time*

No queuing time between two workstations is acceptable and the processing time should be very short. The idea is that a downstream workstation request parts which are provided immediately. The pull control system kanban (Ohno 1988), is an implementation of this idea. According to Littles Law, see for instance Jodlbauer and Stöcher (2006), the inventory equals the lead time multiplied by the average production rate. Thus, the goal zero lead time is very close to the main JIT goal zero inventory.

2.7 *Zero surging*

Only small fluctuations in the production plan are acceptable. In general a smooth final assembly or production schedule (nearly constant production rate and production mix) is applied in JIT systems. Otherwise a high excess inventory or a high excess capacity is needed. Maybe the most challenging task for a JIT environment is to transform high customer demand fluctuations into a smooth required production rate. Some authors developed methods to manage demand uncertainty or demand peaks (Rees et al. 1987; Bartezzaghi and Verganti 1995; Verganti 1997; Co and Sharafali 1997). There is a trade-off between excess inventory and excess capacity (Bradley and Glynn 2002; Jodlbauer and Altendorfer 2010). The general trend is to prefer excess capacity to excess inventory, especially for various finished goods (Schragenheim and Ronen 1991). Thus, real JIT systems need some excess capacity to work with high demand fluctuations and ensure concurrently high service levels. One way to manage demand peaks is to provide extra capacity such as an additional shift or overtime. The classical way of Toyota to manage the situation on which the production falls behind the desired rate is two shifting, whereby two shifts are scheduled per day separated by a down period for catching-up the desired production rate, preventive maintenance or cross training (Schonberger 1982).

3. Model description

In this article, a single-machine multi-item production system is assumed. The scheduled working time T of the production system is predefined as the maximum capacity available. Unplanned idle time t_{UPI} is considered for machine breakdowns, waiting for an order, tool or worker unavailability and planned idle time t_{PI} subsumes all planned breakdowns like preventive maintenance. All production orders are considered for production and have to be produced. Production orders consist

Table 1. Definitions

Symbol	Description
U	Machine utilization ($U < 1$)
U_{min}	Minimum machine utilization ($U_{min} < U$)
I_{JIT}	JIT intensity (see Equation (3))
$t_{P,i}$	Minimal possible processing time per item of production order i
$t_{S,i}$	Internal set up time per changeover of production order i
$t_{AP,i}$	Additional processing time per item due to speed losses of production order i
t_{PI}	Planned idle time
t_{UPI}	Unplanned idle time
T	Scheduled working time
$n_{C,i}$	Number of items needed for customer orders of production order i without any production on stock
$n_{S,i}$	Number of items produced on stock of production order i
$n_{Q,i}$	Number of scrapped items of production order i
n_O	Number of production orders

of items for customer, stock and/or scrap, which are produced by the production system. A set up of the machine is assumed between two production orders. The processing time consists of: $t_{P,i} + t_{AP,i}$. Table 1 presents the notation.

For the cost model, fix as well as variable costs are considered. Fix costs include personnel costs for permanent workers and depreciation of the equipment used. The variable costs are divided into variable processing costs, variable material costs, holding costs and costs for rework or disposal. The variable processing costs include variable costs for energy, spare parts, operational supplements, expendables and set ups and variable costs for variable capacity (for instance: overtime, leasing workers). Variable material costs include the items to produce the parent item. Holding costs occur for items which are on stock. If rework or disposal is necessary for items, then costs for rework or disposal will be incurred. The total costs for the number of items produced on stock are assumed to be higher than for the number of items produced for customer orders because of the holding costs. Assuming enough excess capacity to meet demand peaks, it is beneficial not to produce on stock because of lower costs and earlier effective revenue. For the trade-off between excess capacity and excess inventory, see for example van Mieghem and Rudi (2002), Bradley and Glynn (2002) or Jodlbauer and Altendorfer (2010).

3.1 *Utilization*

Machine utilization describes how intensively a machine is being used to produce items. Thus, machine utilization equals the ratio time used to available time (Cox and Blackstone 2002). The time used is the sum of the run time for all produced items during one time period (for instance one year) plus the set up times for all production orders during the same time period and additionally the unplanned idle time. All produced items consist of items for customers (these items go directly to the next processing stage or to the customer and are free of any faults), items to be produced on stock (these items go first on stock and after some queuing time to the next stage or to the customer and are fault free) and scrapped items. The available time is the sum of all scheduled work time during the time period minus planned idle times during the time period (e.g. preventive maintenance). Summarizing all these ideas yields the following relationship for the utilization:

Table 2. Decreasing utilization by realizing JIT goals

Seven zeros	... has an effect on	results in ...	U
Zero defects	$n_{Q,i}$	$\sum_{i=1}^{n_O} n_{Q,i}(t_{P,i} + t_{AP,i}) \rightarrow min$	decrease
Zero lot size combined with zero set ups	$t_{S,i}$,n_O	$\sum_{i=1}^{n_O} t_{S,i} \rightarrow min$	decrease
Zero breakdowns	t_{UPI}	$t_{UPI} \rightarrow min$	decrease
Zero handling	$n_{S,i}$, $t_{AP,i}$,$n_{Q,i}$,$t_{S,i}$	$\sum_{i=1}^{n_O} t_{P,i}(n_{S,i}) \rightarrow min$, $t_{S,i} \rightarrow min$, $\sum_{i=1}^{n_O} t_{AP,i}(n_{C,i} + n_{S,i} + n_{Q,i}) \rightarrow min$	decrease
Zero lead time	$n_{S,i}$, $t_{AP,i}$,$n_{Q,i}$,$t_{S,i}$	$\sum_{i=1}^{n_O} t_{P,i}(n_{S,i}) \rightarrow min$, $t_{S,i} \rightarrow min$, $\sum_{i=1}^{n_O} t_{AP,i}(n_{C,i} + n_{S,i} + n_{Q,i}) \rightarrow min$	decrease
Zero surging	t_{UPI},t_{PI}	$t_{UPI} \rightarrow min$, $t_{PI} \rightarrow min$	decrease

$$U := \frac{t_{UP} + \sum_{i=1}^{n_O} (t_{P,i} + t_{AP,i})(n_{C,i} + n_{S,i} + n_{Q,i}) + t_{S,i}}{T - t_{PI}} \tag{1}$$

By achieving zero defects, $n_{Q,i}$ is reduced because scrap and rework should be avoided. The two JIT goals zero lot size and zero set ups are considered together because the sum of the set up time per change over for all production orders effects utilization as seen in Formula (1). Therefore, $\sum_{i=1}^{n_O} t_{S,i}$ is minimized by applying these two seven zeros.

If the seven zero zero breakdown is achieved, then t_{UPI} is minimized. Zero handling effects the number of items produced on stock because for these items, extra work for storing and releasing is needed. Hence, the additional processing time $t_{AP,i}$ can also be minimised if the seven zero zero handling is applied. Due to improvements in the set up process, the set up time per changeover also decreases. Finally, zero handling also influences $n_{Q,i}$ because unnecessary handling with scrap or rework should be avoided. Zero lead time effects the same parameters as zero handling because the target is to reduce the lead time.

If the JIT goal zero surging is applied, then the unplanned idle time t_{UPI} is reduced because a production plan with low functions is focused to avoid over and under load. Moreover, zero surging minimizes the planned idle time by avoiding e.g. preventive maintenance so that a production plan with less fluctuation results.

All seven zeros in themselves lead to a decreased utilization. The effects of the seven zeros as JIT goal on the utilization defined in Formula (1) are summarized in Table 2, whereby the seven zeros and the respective parameters which are reduced are listed.

Table 2 clearly shows that achieving the JIT goals by reducing the seven zeros results in reduced machine utilization. If every JIT goal is theoretically reached, the minimum attainable utilization, called minimum utilization U_{min}, equals the fraction minimal possible processing time for produced items for customers divided by the scheduled working time (Formula (2)).

$$U_{min} := \frac{\sum_{i=1}^{n_O} t_{P,i} n_{C,i}}{T} \tag{2}$$

The minimum utilization is the customer required utilization without wasted capacity for not optimized processing times, scrapped items, overproduction, set ups or idle times. Moreover, the minimum utilization (Formula (2)) is less than the utilization (Formula (1)).

4. Discussion

In this section, the utilization formula is analysed more deeply. On the one hand, the gap between machine utilization and minimum utilization is investigated. On the other hand, the influence of the opposing hierarchical goals on utilization is discussed.

4.1 *JIT intensity*

Achieving the JIT goals means minimizing the machine utilization to the value of the minimum utilization in order to produce only the products requested by the customer. Thus, the gap between machine utilization to the minimum utilization can be interpreted as the JIT intensity.

$$I_{JIT} := 1 - \frac{U - U_{min}}{1 - U_{min}} = \frac{1 - U}{1 - U_{min}} \tag{3}$$

The JIT intensity expresses the conformance to JIT measured in how well the seven zeros are achieved. Due to the fact that utilization is a value between zero and one, and the minimum utilization is less than the utilization, the JIT intensity is a value between zero and one. JIT intensity of 1 means that every JIT goal is fully reached. The numerator term one minus utilization describes how much actual excess capacity is available. The denominator term, one minus minimum utilization, indicates the maximum excess capacity that is possible if no capacity is wasted. Excess capacity is one way to manage scrapped items, demand fluctuations, demand peaks, breakdowns and unavailability of tools or workers (the most favoured one especially for many variants of the finished goods) (Schragenheim and Ronen 1991). If a high JIT intensity is achieved, it is possible to reduce the excess capacity by deinvestment or increasing sales, whereby the customer requirements are fulfilled without any additional investment.

The capacity investment enables the system to meet future customer requirements. Especially, if the demand is fluctuating, more capacity invested means higher capability to produce more products, higher excess capacity and a lower utilization. But this costs more money.

4.2 *Long term level*

The classical long term objective is to minimize the capacity invested or equivalently to maximize the utilization. Bradley and Glynn (2002), Jodlbauer and Altendorfer (2010) and Obermaier and Donhauser (2012) pointed out that there is a trade off between capacity invested and necessary inventory. Looking at the utilization Formula (1), the capacity invested determines the scheduled working time T and the minimal possible processing time per item $t_{P,i}$. Whereby, the scheduled working time depends on the number of maximum possible working hours and the number of machines invested. More money employed increases the scheduled working time T and decreases the minimal possible processing time. Recapitulating the long term view, the following statements are equivalent:

(1) Minimizing the fixed costs (depreciation of capacity invested)
(2) Maximizing the machine utilization
(3) Maximizing the capability (less excess capacity) to meet highly varying customer demand or increasing inventory levels to manage demand fluctuations

4.3 *Medium term level*

In the medium term, capacity adjustments are made resulting from demand fluctuations. The number of permanent workers is assumed to be constant in the medium term. Low customer

Table 3. Effects of parameters in the utilization Formula (1) on total variable costs and revenue by short term decisions

Parameter increase of	... effect on costs	... effect on revenue
Number of items for customer orders, $n_{C,i}$	Increase of total variable material costs and variable processing costs	Increase of immediate revenue
Number of items produced on stock, $n_{S,i}$	Increase of total variable material costs, variable processing costs and holding cost	Maybe an increase of future revenue
Number of scrapped items, $n_{Q,i}$	Increase of total variable material costs, variable processing costs and costs for rework or disposal	Maybe an decrease of revenue
Total time needed for set up, $t_{S,i}n_O$	Increase of total set up costs	Maybe an decrease of revenue
Unplanned idle time, t_{UPI}	Maybe increase of total variable processing costs	Maybe an decrease of revenue
Additional processing time , t_{API}	Maybe an increase of total variable processing costs	Maybe an decrease of revenue

demand requires shorter working times, more permanent workers on vacation, less leasing staff or fewer shifts. It may also result in underutilization of workers or excess inventory. In contrast, high customer demand requires introducing overtime, more leasing staff, more shifts, selling pre-produced items on stock or failing to meet customer demand. Moreover, the planned idle time t_{PI} is defined e.g. for preventive maintenance in accordance with the applied shift model. The main focus for the medium term decision level is on flexibility and not on utilization targets. For the medium term, the following statements are equivalent:

(1) Minimizing the variable costs for workers (leasing workers and overtime) by fulfilling customer requirements
(2) Capacity adjustment of the personnel to meet varying customer demand

Maybe the best strategy is to introduce cost neutral or nearly cost neutral flexible working time (Kerkhofs, Chung, and Ester 2008). But there are legal and social limits to exploiting this flexibility.

4.4 *Short term level*

Finally, short term decisions are discussed. Fixed costs for capacity invested and costs for workers are not addressed in the following Table 3, because they cannot be influenced by the short term decisions. The planned idle time cannot be influenced by short term decisions but short term decisions have to handle unplanned idle times. Moreover, only the direct effects of the parameters and no combinations are considered.

Only two parameters in Table 3 lead to an increase of revenues, although the increase of number of items produced on stock accounts only in future to potential revenues. All parameters increase the total variable costs whereby t_{UPI} and $t_{AP,i}$ only increase the total variable costs if additional capacity is required. The expression "maybe an decrease of revenue"means that because of lost capacity caused by quality problems, too long set up times, or unavailability and/or "additional processing times", customer due dates may not hold. Missed due dates cause customer dissatisfaction and possibly lead to reduced revenue. Summarizing the short term view, the following statements are equivalent:

(1) Maximizing profit (maximizing revenue with minimal variable material, processing, holding, rework, disposal and change over costs)

(2) Minimizing number of items produced on stock, number of scrapped items, total time needed for changeovers and idle time and additional processing time
(3) Minimizing the machine utilization
(4) Maximizing excess capacity

In the short term view, minimizing the utilization means to produce efficiently because the losses according to the seven zero philosophy are avoided. Minimizing utilization is equivalent to maximizing excess capacity and this allows high fluctuating customer demands to be met with low inventory levels. In addition, Goldratts idea of throughput in the theory of constraints (Schragenheim and Dettmer 2000), that only sold capacity contributes to the revenue, is incorporated in minimizing the utilization.

Obviously there are some controversial objectives in the long term, medium term and short term. Fixed costs caused by long term decisions force the system to focus on high utilization: this is the classical view of accounting and finance, although there is a well known trade off between capacity invested and inventory needed. The medium term view tries to adjust the workers capacity to the customer demand fluctuations with less cost and maximizes also the utilization. The short term decisions should try to minimize the utilization, because the losses are avoided due to the seven zeros philosophy. This ensures the ability to produce directly for customer orders without any disruption (no quality problems, no machine failures, fewer change over times, no production to stock, no additional production time). Furthermore, total variable costs are minimized by minimizing the short-term utilization. Hopp and Spearman (2008) stated that high utilization causes low costs per unit but low utilization allows high sales. Low costs per unit based on a high number of items which are produced on stock or are scrapped do not contribute to profit. In addition, it is known that working at the capacity limit (Flynn, Sakakibara, and Schroeder 1995), causes quality problems and a very large inventory (Bradley and Glynn 2002; Jodlbauer and Altendorfer 2010). Taking the general objective into account, to maximize the profit, higher sales should be given higher priority than lower costs per unit.

Managerial insight

Combining the JIT philosophy, utilization concept and costs and revenue, two interesting strategies arise. If a high JIT intensity is reached, this means that the production system can follow the fluctuations of the customer demand without any losses according to the seven zeros, then it is possible to reduce the excess machine capacity as well as the flexibility needed of medium term capacity adjustments. A high JIT intensity allows lower capacity invested and requires less work time flexibility. Alternatively, it is possible to increase revenues by increasing sales, whereas no additional investments are necessary.

5. Conclusions

Based on the seven zeros, a measurement for JIT-intensity with corresponding managerial insights is introduced. It is shown that high JIT-intensity on the long term level means maximizing the machine utilization. However, on the midterm planning level, flexibility is the key for success. The utilization at the short term decision level has to be minimized to achieve the seven JIT goals called seven zeros. The minimum utilization is reached if the production is fully customer order oriented (no production on stock) and if there are no fluctuations and disturbances in the system (no set up, no additional production time, no scrap or rework, no idle time). If the utilization is very near to the minimum one, the excess capacity can be reduced. Thus, high JIT-intensity allows lower capacity invested and requires less work time flexibility or gives potential for increasing sales without any investments. Fixed costs based on long term decisions are decreased with high utilization but there is a trade off between capacity invested and inventory levels, respectively between capacity invested and potential for meeting sales requirements in high fluctuation markets. Total variable costs based on short term decisions are decreased with low utilization. Summarizing, the production view in terms of low utilization by fulfilling the seven JIT goals means efficient production. In further research, an empirical study to confirm the presented relationship between JIT-intensity, utilization and profit/revenue should be carried out.

6. Acknowledgement

This paper was written within the framework of the project Robust Strategies for hierarchical production planning (project number L534-G14) funded by the Austrian Science Fund (FWF).

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