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ORIGINAL PAPER

Controlling just-in-sequence flow-production

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Abstract Analyses of the customer-order process in the automotive industry show that the vision of perfectly synchronized material flows in complex industrial production and logistics environments is still far from having become reality. The traditional strategy of maintaining high safety stock levels to counter the effects of ever more variety and uncertainty in the customer demand leads to unbearable cost in today's competitive markets. Moreover, the responsiveness in the complex supply networks remains low. Thus, the goals of short order lead-times and on-time deliveries to customers are often missed. This places urgency onto the implementation of highly flexible logistics and production systems. The concept of just-in-sequence flow-production promises to allow for both accommodating rising degrees of product variety and cost efficiency. However, its success is dependent on reliable logistics and the ability to avoid turbulences within the material flows. Thus, it needs control of the stability of order sequences and intelligent strategies to hedge against any disturbances that cannot be proactively removed in the production flow. This paper suggests the introduction of systematic key performance indicators to make process instability transparent and manageable. Based on that, dimensioning methods for hedging against inherent sequence instability of production processes by means of physical or virtual re-sequencing are presented.

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1 The challenge of turbulence in industrial production

For the largest part of the European automotive industry, meeting highly specific customer demands by product and service differentiation has become the key strategy for success in increasingly competitive world markets [4]. To meet the goal of high customer satisfaction—especially in the premium segments of the automobile markets—product individualization and logistical capabilities take the center stage.

Most automobile producers (original equipment manufacturer, OEM) have implemented a built-to-order strategy to meet the demand for product variety [6, 10], following the mass-customization approach [1, 3]. Critical success factor is the logistical ability of supplying the required component variants just-in-time, as well as the ability to cope with turbulent market development and fluctuating demand, i.e. organizing flexible, highly responsive workflows without compromising delivery reliability and the efficiency of value-adding processes [16]. This results in the requirements for predictable and short order lead-time within the supply network.

Several uncertainty factors impede the realization of these goals. They lead to instable material flows in the supply chain as well as to the demand for very expensive production and logistics systems.

First, the validity and availability of information on the demand of the other partners in the supply chain remain insufficient [20]. Poor information exchange and short time demand changes are causing high levels of safety stocks near the car factories. Especially, suppliers are regarding the bad preview of the OEM demands as a main problem [11].

Second, fluctuations in the quality of production processes result in instable order lead-times. This has significant negative influence on the goal of on-time delivery to the customer. Thus, current logistical planning and control systems do not provide a sufficient solution to combine value-adding efficiency with individual customer satisfaction by product individualization. Consequently, major future goals must be to avoid turbulences of material flows in the supply chain, which are induced by information uncertainty, and to minimize the resulting waste of resources. One current approach of the automobile producers to reach this aim is the control of production and logistics by stable order sequences (see, e.g., [7]). This encompasses two main aspects:

- Just-in-sequence (JIS) material flow in the built-to-order production and supply processes.
- Introduction of a fixed period of time prior to assembly, where the order sequence is reliable ("frozen") for the benefit of the supply chain partners.

Until today, automotive flow-production systems with stable order sequences have hardly been implemented. The uncertainty factors, which cause fluctuations in the OEMs' value-adding processes are little understood and controlled. Only when pre-planned just-in-sequence flows are stabilized, the benefits of the JIS concept will unfold. Otherwise, the potential advantage of the concept is lost, as it will be necessary to invest in sizable re-sequencing buffers. This would just shift waste of resources from upstream in the supply chain into the car production process [14].

This paper reports on a study for methods to assess and analyze production system stability with the aim of improving production flow control.[1] The central challenge is the development of new measurements and re-sequencing tools for realizing JIS-stability in production and logistic processes. In the first section of the paper, the concept of stable order sequences is described. Furthermore, the goals of logistics stability and the main causes of instability are presented. The second section introduces key stability performance indicators for the assessment of the extent of sequence instability in material flow systems. The goal here is to suggest ways for improving transparency with respect to factors, which are negatively influencing stability. Third, several hedging strategies against apparent instabilities are described and methods for re-sequencing are introduced.

[1] This paper is based on parts of the doctorate dissertation of the author [14].

2 The concept of stable order sequences

The central idea of the concept of stable order sequences in production and logistics is that the planned sequence for the process of assembling a series of individualized cars will be strictly "frozen" for a certain period (e.g., some days) before the actual assembly takes place. The assembly lines of today's automotive plants are designed for a flow of car bodies at given cycle times. An important premise is that there will be no changes in the sequence of cars, once they enter the final assembly line—i.e. the "hard" first-in-first-out (FIFO) principle. This requires that the body and paint shops have the task to supply the car bodies just-in-sequence to the assembly line, following the pre-planned assembly order sequence. Figure 1 shows this concept in a value stream diagram. By stabilizing the production process through just-in-sequence control, the OEM can realize short and predictable order lead-times and fixed delivery dates for the customers (see, e.g., [8]).

Once the assembly sequence is determined and the "frozen" period starts, suppliers are notified and expected to prepare for the corresponding just-in-sequence delivery of parts. This provides the suppliers with some flexibility within the time frame of the "frozen" period to optimize their manufacturing and logistics processes, e.g., by producing in economic batch sizes, by assigning production to an optimal production location (if there are alternatives), to minimize safety stocks and materials handling. In effect, the material flows within the supply network are synchronized to the car body flow in the OEMs' plant. This leads to higher over-all productivity by minimization of waste by buffering, extra-handling, and waiting time of supply parts.

To fully exploit these potentials, several obstacles have to be overcome. After the preplanned job sequence is started in the body shop, basically, production control pursues adherence to the order sequence set, following the "hard" FIFO rule. However, several negatively influencing factors like parallel processes, equipment downtimes, and defective or missing parts may cause interruptions and the need for rearrangements of the order sequence. Especially, the notoriously instable paint shop process, which often requires repair loops and parallel work stations, but also quality problems in the body shop do occur. As a result, the pre-planned assembly sequence is not kept. JIS-supply parts have to be re-sequenced in costly and little predictable ways to adjust to the ad hoc revised actual job sequences after those unplanned events.

In summary, there are five main influences on sequence stability [14]:

- Process control effectiveness
- Material supply reliability
- Process quality

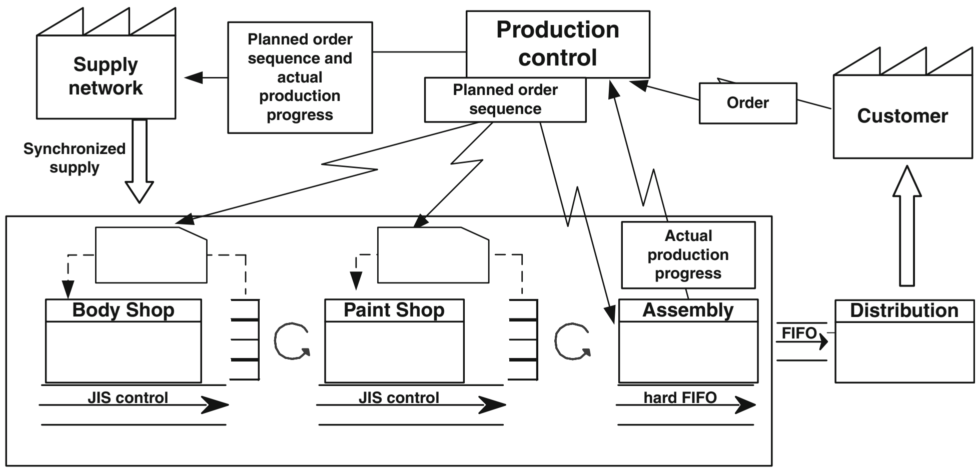

Fig. 1 Production control by fixed order sequence

- Product planning stability
- Infrastructure and layout design of the plant

Automotive producers follow different strategies to cope with the instability in their production processes [8, 15]. Most of them use either physical re-sequencing by automated storage and retrieval systems or virtual re-sequencing by late order assignment to re-arrange the order sequence before the final assembly starts. The most common response to instabilities in order sequence, hence, is reactive through hedging. Only a few manufacturers focus on proactive and preventive approaches to by stressing higher process quality and reduction of buffers in the pre-assembly phases of processes such as the body and paint shop. The Japanese company Toyota, for example, realizes a FIFO-oriented flow with small buffers, thereby minimizing lead-times [17]. This is based on high process discipline and the rigorous elimination of any potential causes for disruptions within the production. The orientation on continuous flow with short and stable lead-times and order cycle times is rarely seen in the plants of other manufacturers, especially in the premium car segment. Reasons for this are in very high levels of product diversity at lower total production volumes, but also in a lack of experience with integrated flow-production systems [16].

Despite the outstanding relevance of the problem of stable order sequence control for the built-to-order production, it has received relatively little academic research attention so far. In the German literature, the dissertation by Weyer [21] describes general strategies and classification approaches of the concept. He, first, discusses several key performance indicators, e.g. for the measurement of sequence quality. Inman [12] is proposing dimensioning procedures for automated storage and retrieval systems as well as a concept for late order assignment for the restoration of the original sequence. Ding and Sun [5] propose the buffering of backup car bodies to restore the sequence by substitution of the missing car bodies. Gusikhin et al. [9] are introducing a method for the early initiation of car bodies with low probability of meeting due dates, in order to compensate the anticipated scrambling. In this author's dissertation [14], on which this paper is based, a catalog of logistical methods for designing stable order sequence production control is developed.

The central goals of logistical stability are shown in Fig. 2. A generalized process of stabilizing production flows will have to consider four systematic steps: analysis, design, measurement, and control of the production system. This paper focuses on the two last steps. In its following sections, first, approaches to measuring the stability of order sequences are described and key performance indicators for the evaluation of stability of built-to-order production are provided. Second, methods for the flow control are provided that allow a hedging against inherent sequence instability of production processes by means of physical or virtual re-sequencing.

3 Measuring of sequence stability

The basis of the measurement of sequence stability is the assessment of the position of each element in a sequence (i.e. in the context of automobile production: an element is an order of an individually specified car or the assigned car body). This is done by comparing the position in the actual

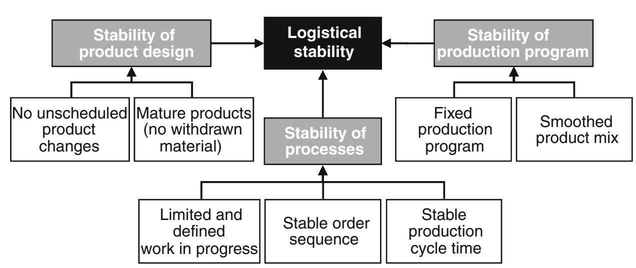

Fig. 2 Goals of logistical stability in flow-production [14]

production sequence (output) to that element's position in any other earlier physical or planned sequence (input). Numbers for each position are assigned in ascending order, i.e., the later an element is positioned, the higher the assigned number. Number assignments can be done either to job orders or to car bodies. Idle cycles are not covered by the position numbering, so that sequence position and cycle time number are not the same.

3.1 The sequence displacement (SD)

Inman is proposing to define the sequence displacement as the difference between an order position in the body shop sequence and its position in the paint shop sequence [12]. Here, a more general definition is given. The sequence displacement (SD) of a sequence element *i* (e.g., a car body or the respective order) is given, comparing two sequences at a certain moment within the production process, as:

$$SD_i = \text{output-position}_i - \text{input-position}_i. \quad (1)$$

The sequence displacement defines the actual distance of the sequence position of an object to its position within the input or pre-planned sequence. This corresponds to the strength of the sequence scrambling for a specific element and it measures the FIFO-adherence. Too early elements are resulting in a negative SD, too late elements have a positive SD. Figure 3 gives an example.

The SD-distribution plot of the sequence elements depicts the sequence stability: the smaller the distribution, the more stable the sequence. Orders with zero SD are considered in sequence. The average absolute sequence deviation (ASD) is an appropriate measure of statistical dispersion. This performance indicator reflects the strength of the sequence scrambling.

3.2 The sequence adherence (SA)

The sequence adherence (SA) can be defined as the "goodness" of a sequence. It measures the ratio of the amount of sequence violations and the number of elements that are in the correct sequence. For a sequence of *n* elements and a number of violations, *v*, there can be defined:

$$SA = 1 - \frac{1}{n}\sum_{i=1}^{n} v_i [\%] \quad (2)$$

In order to define sequence violations through particular cars or orders, it is possible to constrain the measure only to those elements that are too late. This is reasonable, since car bodies, which are too early, can be buffered and easily re-arranged in sequence, whereas late ones possibly miss the deadline for reaching their planned assembly sequence position. By definition, the SD of sequence elements is not independent. The actual positions of sequence elements are mutually influenced. Earliness through preponing of orders as a pulling ahead of car bodies is then indirectly punished more severely than lateness. This is due to the result of a couple of overtaken cars, which get a positive SD. For a just-in-sequence production and logistics control, preponing should anyway not be allowed, because supply parts might not yet be available. Thus, early sequence elements are only a result of others that have fallen behind.

In order to determine, which car bodies or orders are actually too late (the output-position, *out-p*, is greater than the input-position, *in-p*), the SD has to be calculated iteratively. Sequence elements with positive SD have to be successively eliminated, following the descending output-positions. Figure 4 displays the corresponding algorithm. ASD and SA are the key performance indicators to evaluate the stability of a sequence in a concentrated manner.

3.3 The sequence backlog (SB)

Another central performance indicator for just-in-sequence control is the sequence backlog (SB). It is a time-related indicator that reflects at a certain measuring point how many sequence elements are missing behind the current element, compared with the input-sequence. The sequence backlog for each element of a sequence, *n*, can be calculated, following the algorithm in Fig. 5. Alternatively, it

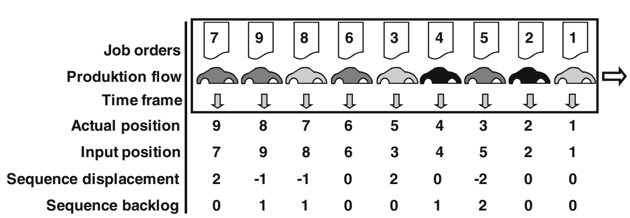

Fig. 3 Determination of the sequence displacement and the sequence backlog [14]

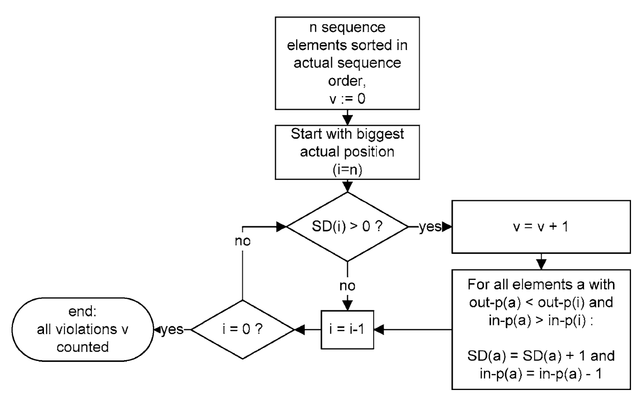

Fig. 4 Algorithm for calculation of sequence violations by means of the sequence displacement [14]

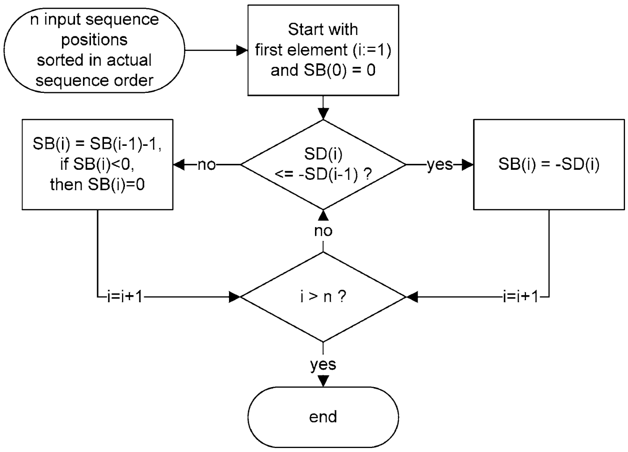

Fig. 5 Algorithm for calculation of the sequence backlog [14]

can be derived from the input-positions in the ascending actual sequence order, following these rules:

- If the difference between the current input-position and the so far biggest input-position is bigger than 1, then the SB increases by this difference.
- If the actual input-position is smaller than the so far biggest, the SB shrinks by 1 (until SB = 0).

The sequence backlog is an indicator for the number of missing (too late) sequence elements at any measuring point. Regarding a certain time frame, the maximum SB, which is the same as the minimum SD, measured at the final assembly reflects, e.g., the number of (JIS-) parts for the missing car bodies that have been buffered at once. By means of the SB_{max}, intermediate buffers can be dimensioned for the re-sequencing of supply parts.

3.4 Sequence displacement and lead-time

The sequence displacement is a relative measure that enables the assessment of the FIFO-adherence in production. In quasi-static flow systems with a defined cycle time, lead-time and sequence displacement can be transformed into one another. The process lead-time in such a system encompasses three main influencing factors: WIP, cycle time, and sequence displacement. The lead-time of a certain car body, LT_i, between entering the system, en, and its exit, ex, would be as follows:

$$LT_i = (SD_{rel,i}^{en-ex} + WIP^{en})ct_{eff}, \quad (3)$$

whereby ct_{eff} is the effective cycle time of the system outlet during the car body's passage. This calculation of lead-time has the advantage that equipment downtime and breaks do not have to be explicitly measured. When the average within a certain period is calculated, Little's law is valid, since the average SD is zero.

4 Hedging against sequence instability

There are two main strategies to realize stable sequences in material flow:

- Control of sequence stability by eliminating process weaknesses and by realizing high process discipline
- Hedging against sequence instability by means of re-sequencing methods

Here, only the latter strategy will be discussed (for concepts that support a control of sequence stability see, e.g., [14]). For the remaining part, this paper, hence, concentrates on those situations where changes in actual production sequences are not avoidable by any proactive measures, so sequence rearrangements have to be coped with by hedging strategies. Re-sequencing, in principle, can be done either by re-sorting the car bodies, or by virtual re-sequencing through flexible order assignment.

4.1 Flexible order assignment

In order to realize virtual re-sequencing, the production order is assigned only temporarily to the car body. A re-assignment of an order to another car body is possible. This is usually done by swapping the orders of two vehicles (see, e.g., [12, 14]). Thus, the order flow and the material flow are decoupled. This is also practicable for built-to-order production. Car bodies are produced following the actual customer orders, but the final connection between car body and customer order is performed at the time of final assembly. At best, the car body sequence at assembly is equal to the pre-planned order sequence.

Flexible order assignment can only be realized, if there are "barter partners" available that are fitting. The more different car body variants are in the process and the earlier the variants are defined within the process, the lower is the probability of finding alternatives of car bodies with the similar characteristic to successfully do the bartering. One has to either reduce the number of car body variants or realize a postponement strategy (see, e.g., [2]). Both strategies have the goal to reduce the body-in-white variants without reducing the customer-relevant options and keeping a high external variety, since this is a central concern of the customers [10].

There are generally two ways of flexible order assignment. Either the job orders of the pre-planned sequence search for the best fitting car body in the process, or the car bodies in the actual production sequence at a certain measuring point are consecutively assigned to the earliest possible and fitting customer order (for a detailed algorithm description see [13]).

4.2 Introduction, dimensioning and control of re-sequencing buffers

An alternative or supplementary strategy is to introduce buffers into then automotive production flow. Buffers have the function of

- Decoupling and interception of disturbances
- Overcoming of physical distances
- Re-sequencing of car body sequences

This paper focuses on the re-sequencing function with the task to reconstruct the originally planned sequence or the system's input-sequence. There is a variety of different buffer systems used in automotive production. The two main types regarded here are

- Automated storage and retrieval systems (ASRS)
- Mix-banks (MB) as a set of parallel lanes

In the following, methods for dimensioning and control of the re-sequencing function through the two buffer types are presented. First, ASRS systems are regarded (for current research on ASRS-buffers see, e.g., [18]). Second, control algorithm for MB systems are proposed and evaluated.

ASRS-buffers with random access to each car body are mainly used between the three shops in automotive production. Often, they are installed after the paint shop before the painted body shells enter the final assembly. For the use within JIS production control, the task of the ASRS-buffer is to resequence the car bodies in ascending input-positions, following the original order sequence (the "oldest" order first). The necessary size of the buffer to perform this task is depending on the degree of the sequence scrambling in body shop and paint shop. For the dimensioning of the re-sequencing function, two input information are necessary that can be determined either by process simulation or by measuring real process data: the actual sequence (before entering the buffer) and the planned sequence, which has to be restored. Then, the sequence displacement of each car body can be calculated. For a full restoration, the ASRS size depends on the most positive sequence displacement $\left(SD^{+}_{max}\right)$, thus, on the car body with the greatest lateness, as Inman shows [12]. If this car body cannot overtake the whole buffer content and has to be stored first, the necessary buffer dimension for a full restoration of the original sequence would be:

$$size_{SA=100\%} = SD^{+}_{max} + 1. \quad (4)$$

If the re-sorted sequence needs not to be equal to the original sequence, thus, if the resequence requirement of 100% can be dropped, the buffer size can be reduced. Therefore, the sequence elements with the greatest lateness

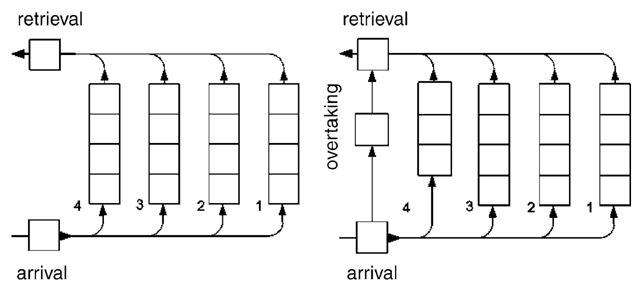

Fig. 6 Example of mixed-bank buffers with and without overtaking lane [14]

have to be successively removed from the amount of elements regarded (as shown by [12]).

The most common buffer type in automotive production is mix-banks. An example is given in Fig. 6. By means of the parallel lanes, the car bodies can be re-sequenced depending on the sorting goals (for optimization of color batches in mix-banks see, e.g., [19]). For the re-sequencing, three factors are crucial: the lane selection policy for the car body at the arrival point coming from upstream operations, the selection policy of the first car bodies on the lanes at the retrieval point, and the buffer configuration. Here, methods for re-sequencing car bodies are proposed that allow decentral decisions at the arrival point and at the retrieval point of the buffer. The goal is to achieve an order sequence that primarily maximizes the sequence adherence in comparison with the pre-planned order sequence. The second re-sorting goal would be the minimization of the ASD. That means that the car bodies have to be

- stored with ascending positions of the planned sequence and
- retrieved successively starting with the smallest available position of the planned sequence.

The SD of a car body is reduced by the actually overtaken content of the buffer. For the dimensioning of mix-bank buffers, simulation is needed, since the necessary buffer size is dynamically depending on the buffer configuration, the input-sequence, and the buffer content. The cycle time is set to be constant.

First, for every branch of conveyors, a lane has to be selected for each car body arriving for storage. Therefore, the positive difference between the planned sequence position of the car body arriving and the planned position of the last car body of each lane is calculated. The rules for lane selection are as follows:

- The car body is stored in the lane with the resulting smallest positive difference. Thus, an ascending sequence of car bodies is achieved.
- If this is not possible, an empty lane is selected.

- If both are not possible, the lane with the smallest absolute difference from the pre-planned sequence positions is selected. As a result, the resulting SD is minimized.

If there are equivalent possibilities at the same time, the lane can be selected by criteria like conveyor cycle time or traveling time, which are not considered here.

At the exit of the mix-banks, the car body that is going to be retrieved next needs to be selected. The re-sequencing algorithm determines the retrieval by choosing the car body accessible with the lowest planned sequence position.

In order to resequence car bodies with great lateness, special conveyors for overtaking the whole buffer content can be installed. Figure 6 gives an example on the right hand side. The algorithm for this action would be to choose a car body for the overtaking lane, if the planned sequence position of the car is lower than any of the other car bodies' planned position in the buffer.

4.3 Configuration and re-sequencing performance of mix-bank buffers

The assessment of the re-sequencing performance of the developed algorithms is performed by simulation of an exemplary buffer model. First, the mix-bank buffer has the configuration of four lanes, each with the holding capacity of 10. The filling level is fixed to 70% at the beginning.

In a further step, the buffer configuration is changed. A new conveyor lane is added, which allows an overtaking of the whole buffer content, as shown similarly in Fig. 6 on the right side. In order to keep the total buffer capacity of 40 places, one of the four other lanes has only a holding capacity of 9.

After simulation, the results of the mix-bank re-sequencing algorithm are compared to those of a FIFO-buffer as well as an ASRS-buffer with the same capacity. Figure 7 shows the SD-distribution plot at the buffer exit in comparison with the originally planned sequence. Comparing the FIFO-buffer to the re-sequencing mix-bank buffer, the impact of the re-sorting is clearly visible. The best results are achieved by an ASRS-buffer with random access to each car body.

Table 1 gives the respective simulation results by means of the sequence quality ratios sequence adherence and average sequence displacement. Especially, the SA shows the effectiveness of the algorithms, whereas the ASD is not changed drastically. This is due to the fact that car bodies with great lateness can only reduce their SD strongly limited to the overtakable buffer content. Thus, the introduction of the overtaking lane causes a further reduction of the ASD. The respective simulation results are not far from those of the ASRS-buffer.

For an assessment of the optimal mix-bank buffer configuration, two sensitivity analyses are performed. First, the buffer filling level is varied. If the buffer is too full, the choices for the lane selection are limited. If the buffer is too empty, the late cars cannot sufficiently overtake earlier ones. Second, the buffer configuration is changed, altering the holding capacity and the number of lanes.

Figure 8 shows the results of the buffer filling level variation between 20 and 90%. The re-sequencing performance reacts not very sensitively to the variation of filling levels between 50 and 70%. The optimal buffer filling level lies around 50%. With an overtaking lane, it is best between 50 and 70%.

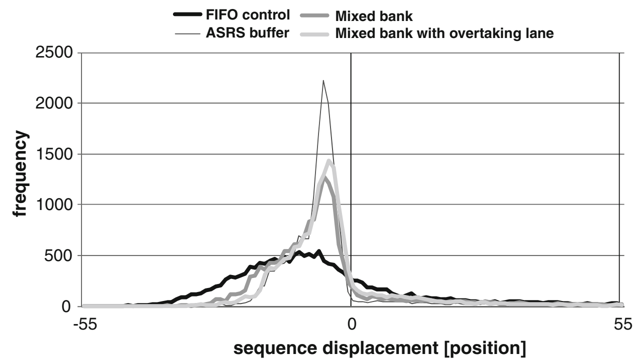

Fig. 7 SD-distribution plot of the re-sequencing results of different buffer configurations [14]

Table 1 Re-sequencing results of different buffer configurations [14]

	Sequence quality ratio	
	SA [%]	ASD [Position]
FIFO-buffer	28,2	21,8
Re-sequencing by mix-bank buffer	74,2	17,0
Re-sequencing by mix-bank buffer with overtaking lane	74,2	14,1
ASRS-buffer with random access	86,9	13,6

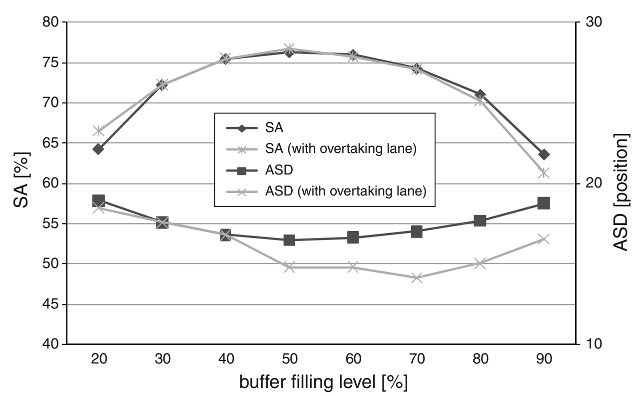

Fig. 8 Re-sequencing performance with variation of the buffer filling level [14]

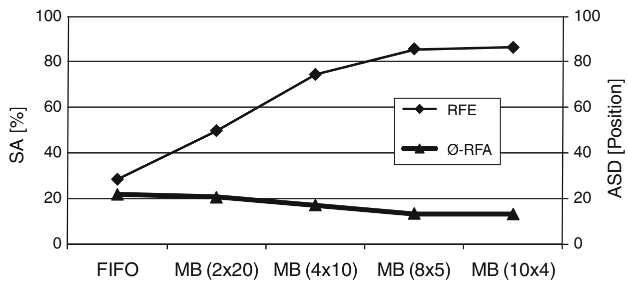

Fig. 9 Re-sequencing performance with variation of the buffer configuration [14]

Table 2 Simulation results comparing physical and virtual re-sequencing [14]

	Sequence quality ratio	
	SA [%]	ASD [Position]
FIFO-buffer	40,1	19,7
Flexible order assignment	19,4	9,5
ASRS-re-sequencing buffer (size of 60)	93,3	9,2
Flexible order assignment and ASRS-buffer (size of 60)	98,5	0,9

Figure 9 reflects the simulation results with variation of buffer configurations. The buffer filling capacity of 40 is distributed on two lanes (2 × 20), four lanes (4 × 10), 8 lanes (8 × 5), and 10 lanes (10 × 4). The re-sequencing performance rises with the number of lanes. Thus, the design recommendation is to realize as many parallel lanes as possible. Here, already four lanes offer a reasonable result.

Ideally, re-sequencing buffers and flexible order assignment are combined. The virtual re-sequencing makes a compensation of great lateness possible, which is reflected in the change of the ASD. Buffers, however, focus on re-sorting of smaller scrambling, which primarily betters the sequence ratio SA. Moreover, buffers are independent from the variance of car bodies in the process that limit the effectiveness of flexible order assignment as discussed above. Table 2 shows the respective sequence quality ratios and substantiates the advantages of the combination of physical and virtual re-sequencing. The simulation of the flexible order assignment is performed with the order-centered algorithm (presented in [13]).

5 A promise for the automotive industry

The competitiveness of automobile manufacturers is highly dependent on the degree to which they are able to meet their customers' ever more differentiated wants and needs, while not compromising the efficiency of their value chains. A JIS control of production and logistics processes can support simultaneous achievement of those goals. Sequence stability offers the chance to minimize the "uncertainty" in short-term planning of the supply chain partners by realizing a "frozen" order sequence and precisely sequenced "pulling" of parts from suppliers. A higher adherence to order sequences once set leads to less re-sequencing and handling of JIS-supply parts, to smaller safety buffers, and a smoother overall production flow.

The primary goal must be to succeed in stabilizing the car body sequence by focusing on the reduction of buffers and eliminating process instabilities. This can be achieved by realizing a stable flow-production system based on a series of principles and methods (see [14]). However, proactive stabilization may never be perfect. Intelligent hedging against remaining instabilities is therefore necessary.

The paper presented some key performance indicators to systematically measure the sequence stability of built-to-order production processes. The average sequence displacement and the sequence adherence are the two main measures to assess a sequence quality.

There are two main strategies to re-sequence the scrambling of an order sequence. Re-sequencing can be performed either by physically re-sorting the car bodies, or by virtually re-sequencing through flexible order assignment. Here, methods for dimensioning and control of buffers for physical re-sequencing are elaborated. As simulation results show, mix-bank buffers with an adequate control algorithm can be nearly as effective as ASRS-buffers, if they are appropriately designed. The combination of re-sequencing buffers and flexible order assignment shows the best performance and makes a high-sequence quality possible, despite instable processes.

The overall goal of the JIS production control approach is to synchronize the material flow within the supply network and to reduce safety stocks and material handling. By means of the strategies and methods suggested here, the automotive industry can realize improvements in productivity by rationalization of both, internal workflows and processes in the supply-network.

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