RELATIONS BETWEEN ROOT-CAUSES OF DELAYS AND THEIR DURATION IN A SMALL BATCH PRODUTION

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Abstract

The paper is an analysis of relations between root-causes of delays and their duration. The article is based on data gathered during a case study research in a small batch production company based in Silesia district in Poland. During the research, the root-causes of delays were determined. The distribution of the delays duration is presented. The differences in the most frequent reasons of the delays in different delay duration ranges are shown and explained. The paper is a part of a research on delays in a small batch and multi assortment production.

Keywords: Production, delay, small batch, relation

1. INTRODUCTION

This paper is a result of a greater work on on-time deliveries in a small batch and multi assortment production system. The data for the analysis was obtained in ANGA Mechanical Seals Ltd. The data consists of the list of delays, their root-cause and duration. The list was created on the basis of delays that happened in the firm in 2014 in a selected group of products. The on-time delivery rate for this group of products in the company is high - over 90%, but due to the small batch and multi assortment production the researchers had an access to 315 independent delay cases.

2. LITERATURE REVIEW

Due to the high variability in the small batch and multi-assortment production it is difficult to precise determine the deadlines of delivery to the customer standard periods of time needed for production.

A term “on-time delivery” is related to reliability. It is a rate between product shipments on-time and all of the product shipments. The term is a measure of reliability [10]. The reliability of the deliveries is a skill of keeping to the promised due dates [12] or keeping to the due dates in a schedule [8]. A delayed order is an order shipped to the customer after the due date. The researches proved that reliability is one of the most important factors in sustaining the customer loyalty [7] and a key factor of competitiveness of the firm [4, 13, 1].

There are papers that shown a positive impact of TOC (Theory of Constraints) implementation on on-time delivery [9]. Wieters [14] presented opinion that high transportation costs and scheduling problems are the main contributors to the problems with on-time deliveries. There is also a paper that lists some causes of the delays on the basis of surveys with 15 companies [2]. However, a case study research may be more useful to correctly determine the root-cause of the delay. Determination of the root-cause of a delay is crucial. This is a difficult process in which the researcher needs to understand the whole production process, possible solution to the problems that occurred in a case, environment of a company, technology and the product itself. It is important to find the real root-cause. There are some tools and methods that can help the researcher in this task, like a fishbone diagram [5] or 5-Why method presented in work of Ohno [11]. This is an extensive subject and this paper is not focused on this part of the research. More on this topic can be found in a paper on determination of the root-causes of the delays [6].

To the best knowledge of the authors, it seems that there is a gap on the subject, and a need for the paper on the relations between the root-causes of delays and their duration in a small batch and multi assortment production. The aim of this paper is to narrow this gap.

3. DELAY ROOT-CAUSES

Twenty six root-causes which can be grouped into 5 categories where determined during the research. They are listed below (category: root causes):

1) Delays of material deliveries:
   - delay of a material delivery caused by a supplier,
   - human error in a material order preparation - material ordered too late,
   - insufficient level of delivered material quality,
   - lack of reaction to an apparent material delivery delay,
   - not ordering a needed material in an appropriate quality or quantity,
   - transportation delay caused by a transport company,
   - human error in a service order preparation - service ordered for a too late delivery date.
2) Delays related to planning:
   - mistake in a production plan preparation,
   - mistake in a service duration estimation,
   - mistake in a material delivery date planning,
   - mistake in a production balance planning (production processes),
   - mistake in testing rigs balance planning.
3) Delays related to technological problems:
   - defect caused by a production worker during technological operation,
   - faulty design of a part or a product,
   - faulty technical plan of production (technology),
   - hidden fault of a material,
   - human error in a technical documentation preparation made by a designer,
   - technological problem caused by a service company,
   - the design of a part or a product on a verge of technical boundaries within the company.
4) Delays related to production procedures and control:
   - mistake in a production control - not fulfilling the production schedule,
   - mistake in a production control - not fulfilling the production schedule operation queues,
   - not keeping sufficient human resources on the shop floor,
   - procedures and standards of the production control.
5) Other (e.g. unplanned absence of a worker, lack of reaction to a visible service delivery delay etc.).

4. GENERAL DISTRIBUTION OF DELAYS AND THEIR FREQUENCY

The delays have different impact on the production cycle. The duration of the delay adds up to the standard production time, so it makes it longer to satisfy a customer. The delays can be less or more severe. **Fig. 1** shows the distribution of all of the delays analysed in the research.

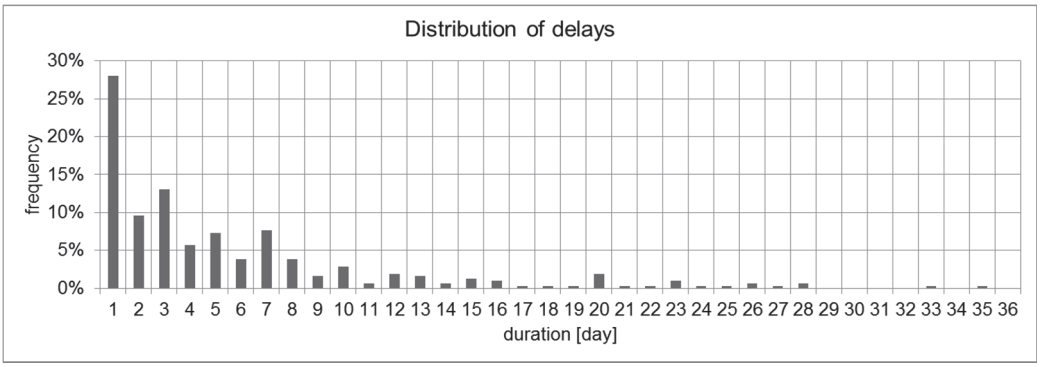

Fig. 1 Distribution of delays

Table 1 shows the frequency of the delay category in different ranges. The ranges where chosen on the basis of customers perception of the delay duration in the company's opinion: 0-3 days delay is usually a minor inconvenience. 4-7 days is most often not a big problem, although this delay is more visible to a customer. 8-14 days delay is usually a serious problem in customers' eyes while delay duration over 2 weeks can significantly spoil the company's reputation. Basically, the longer duration the bigger the problem.

Table 1 Delays in ranges

Delay Category	Frequency [%]				
	whole range	0-3 days	4-7 days	8-14 days	more than 14 days
Delays of material deliveries	31	19	38	48	55
Delays related to production procedures and control	16	24	12	0	5
Delays related to planning	31	40	30	25	8
Delays related to technological problems	15	11	13	23	29
Other	6	6	7	4	3

Table 1 shows that different delays are more dominant in different ranges. The frequencies of the delay causes categories "delay of material deliveries" and "delays related to technological problems" are increasing within the duration of delays, while "delays related to production procedures and control" and "delays related to planning" are decreasing within the duration of delays.

5. IMPACT OF DELAY CAUSES ON DELAY DURATION

To better understand the results, **Figs. 2 - 5** present distribution of delays duration for different delay cause categories.

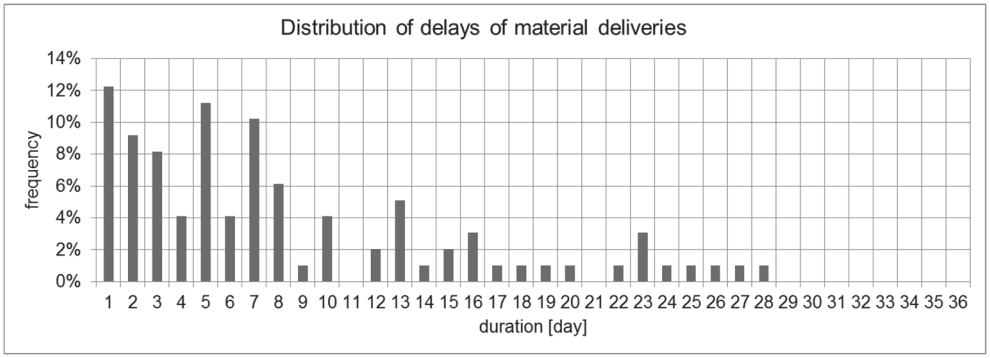

Fig. 2 Distribution of delays of material deliveries

The distribution of delays of material deliveries is the most uniform among other analysed. 84% of all of these delays is a root-cause “delay of a material delivery caused by a supplier”. Material delivery dates are usually boundaries, starting points for a production. It is very rare for a supplier to inform about a material delay that will occur in a future. Usually, the material is just not delivered on-time. This importantly reduces the possible solutions that can overcome the problems caused by the material delay.

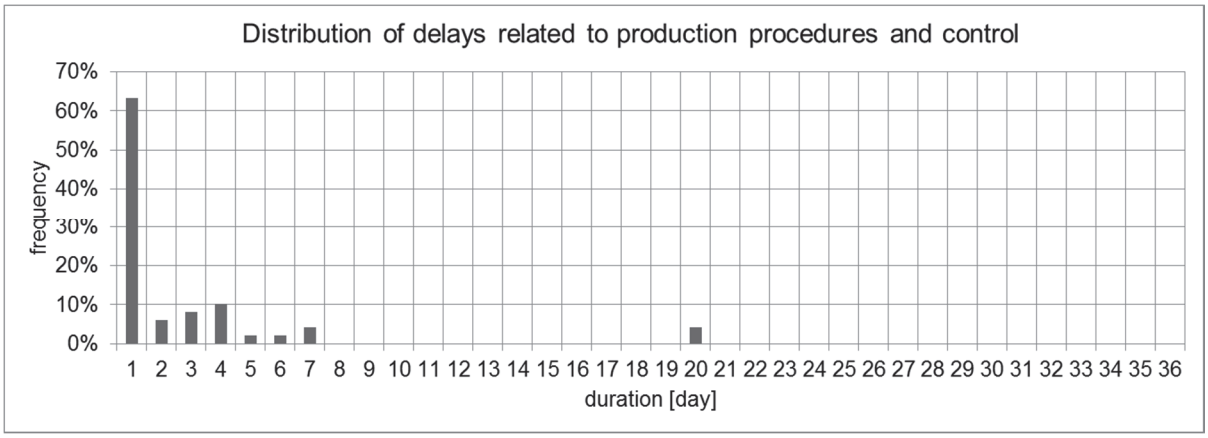

Fig. 3 Distribution of delays related to production procedures and control

It is surprising that delays related to procedures and control of a production are such a large group of delays. These procedures should ensure reliability of the production system. The biggest contributor in this category is the root-cause “procedures and standards of the production control”. It accounts for 61% of all root-cause delays in this category.

The reader should take into account that these procedures and standards where imposed for different reasons, like compliance to international production standards (e.g. ISO/AS standards), to limit production costs etc. The analysis is focused on delays, but the procedures and standards may have resulted in on-time deliveries for some other orders, which would be delayed without these procedures and standards. Nevertheless, the procedures and standards should be periodically analysed and be either dropped or improved.

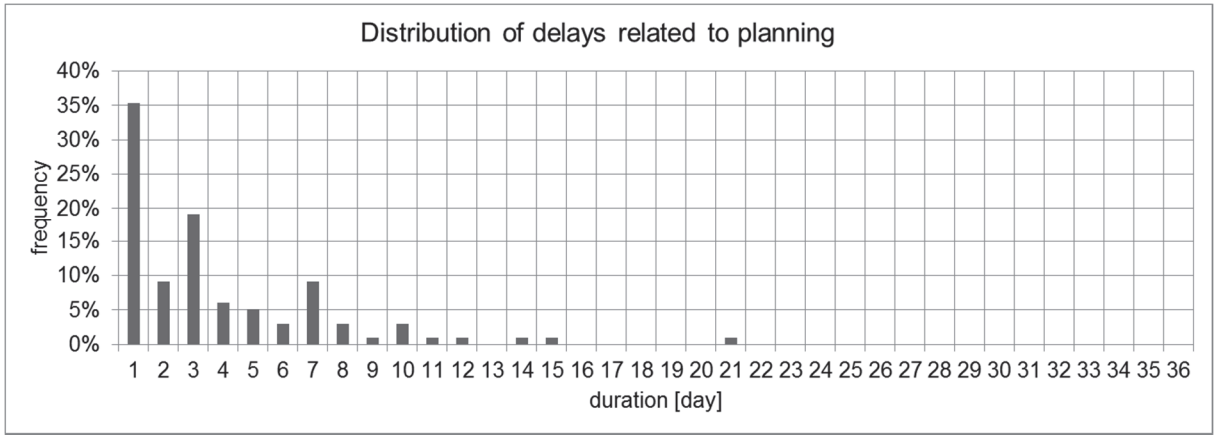

Fig. 4 Distribution of delays related to planning

The distribution of delays related to planning show that these delays last up to two weeks. The most significant contributor to these delays is a root-cause “mistake in a production balance planning (production processes)”. It accounts for 42% of all root-cause delays in this category. It should be noted that balancing production is a process that involves prediction of the future resources, where in reality many unsuspected events may occur. It can be taken into account by an efficiency factor, but the factor value never equals the reality.

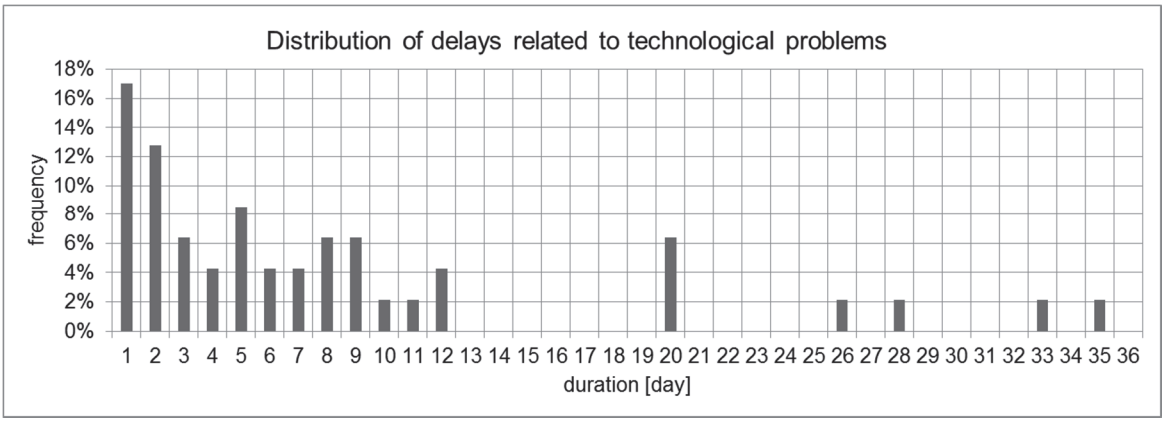

Fig. 5 Distribution of delays related to technological problems

The range of delay duration caused by technological problems is wide and more uniform than two previous categories presented. The biggest contributor root-cause is a "defect caused by a production worker during technological operation", and accounts for 40% of all delays in this category. The duration of these delays is determined by both the nature of the problem that occurred (e.g. scratched surface of a part) and the remedy (e.g. polishing of the surface within the company). The more difficult problem to solve, the longer the duration of the delay. It should be noted that sometimes, a technological problem results in a scrap, and a new material must be bought.

To picture the differences in the delays' durations, **Table 2** provides their basic statistics.

Table 2 Basic statistics of the delay causes

Delay cause category	Mean	Dominant	Median	Standard deviation
Delays of material deliveries [day]	9.4	1	7	9.5
Delays related to production procedures and control [day]	2.7	1	1	3.9
Delays related to planning [day]	4.2	1	3	5.2
Delays related to technological problems [day]	12.7	1	6	20

Although the delays last different time periods, they have something in common. All of the delay categories have the dominant value equal to one day. It is optimistic that the research data analysed shown that the biggest group of the delays are in the 0-3 range, which is the least inconvenient to customers.

Table 3 presents p-values of the two sample test procedures performed in Minitab 16, where H_0: $\mu_i = \mu_j$, H_1: $\mu_i \neq \mu_j$, $\alpha = 0.05$.

Table 3 Statistic test procedure results

	Delays of material deliveries	Delays related to production procedures and control	Delays related to planning	Delays related to technological problems
Delays of material deliveries	-	0.000	0.000	0.291
Delays related to production procedures and control	0.000	-	0.057	0.001
Delays related to planning	0.000	0.057	-	0.006
Delays related to technological problems	0.291	0.001	0.006	-

As results in **Table 3** indicate, there is not a statistically significant difference between delays' duration related to technological problems and delays related to material deliveries. These delays' duration means are significantly different to other delays. Means of delays related to planning and delays related to production procedures and control are statistically indifferent. This shows that having different root-causes of delays does not mean that these delays duration will be different.

6. CONCLUSION

The paper presented the general distribution of delays. The frequency of different root-cause categories in different ranges were shown. The difference in impact of these causes on delay durations and its trend were pictured. The distributions, statistics and sample test results for the delays and were presented and commented.

Delays related to production procedures and control result in the shortest duration - over 60% of these delays lasted just one day. The delays caused by planning were more severe. They usually resulted in up to two weeks delays, but the majority of delays lasted under 4 days. The technological problems and material delays showed to be the most negative causes.

The hypothesis tests have shown significant relation in delay durations between delays related to technological problems and material deliveries' delays, and between delays related to planning and delays related to production procedures and control.

The severity of a delay depends on its cause. In case of a production control and planning, the process of production is affected but the problems can be most often solved within the company. Routine remedy for planning failures is working overtime, which is an expensive solution. Technological problems may be different, but solutions of these problems usually involve some additional effort, e.g. a technical operation that was not planned in the production process. These operations are needed to repair a part or a product. Sometimes the operation cannot be performed within the company, and the problem solution is dependent on business partners or suppliers. In such a case a company has little influence on a duration of a delay.

Material delivery delays are the most problematic category of root-causes of delays, as a company has the littlest impact on the time of problem solving due to the reliance on its suppliers. Small batch and multi assortment production companies are rarely main customers of their suppliers, because they need many different suppliers in multi assortment production. This makes the process of limiting the damage caused by these delay causes even more difficult.

A distribution of delays is a sum of all distributions of basic root-cause delays. One should examine these root-causes frequencies and distributions before implementing measures that are to improve on-time delivery rate. Otherwise the desired positive effect of an on-time delivery improvement may not be satisfactory.

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