AN ANALYSIS OF OCCURRENCE OF THE HIDDEN FACTORY PHENOMENON IN PRODUCTION – BASED ON THE SELECTED YIELDS – CASE STUDY

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Abstract: This article describes a procedure for identifying the phenomenon of 'hidden factory' based on classic and Six Sigma yields, a term attributed to wastefulness during production. The paper presents a study that aims to establish a method for improving the efficiency of production by eliminating this wastefulness. The first part of this article presents a synthesized review of the current literature regarding the negative influence of the 'hidden factory' on production efficiency. The theoretical considerations involve a case study with quantitative data collected from a metal foundry of Zawiercie in Poland, which specializes in producing iron castings, including connectors for water, gas, and vapor installations, as well as minor machine castings. The results indicate a hidden factory within this company's production line. The analyzed example underlines the efficiency of the applied method for detecting the undesired phenomenon of the 'hidden factory.'

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Introduction

Growing competition as a result of globalization is causing production companies to search for new ways of improving their financial gains. In many areas, the fiercely strong rivalry between competitors makes it impossible to raise the product prices that would quickly and directly lead to financial success. Porter (1979) stresses that except for the intensity of competition in a given branch, four other factors can influence profitability in varying degrees, though managers, especially production managers, have little influence on these factors. Nevertheless, there are other areas, as defined by Gryffin (2010), where their efforts can achieve smooth and efficient operations in managing production. This article focuses on one such area, the problem of the 'hidden factory,' which directly influences the efficiency of manufacturing and consequently, the final financial outcome of a company.

Literary Review

The Phenomenon of the 'Hidden Factory'

Harry and Schroeder (2005) defined the 'hidden factory' as all processes, activities, and systems aimed at correcting errors arising in the various stages of production. Miller (2001) stated that the 'hidden factory' does not lower the fulfillment of client's expectations (most frequently expressed in a nominal value and tolerance limit). To the contrary, to a large degree, it increases the company's requirements for fulfilling client's expectations. Miller (2001) also underlined that it generates problems connected with costs, which usually increase due to the lack of awareness of such a phenomenon. According to the research of Kosiny (2013), the savings resulting from the reduction of the costs connected with the 'hidden factory' are directly proportional to the savings from Six Sigma projects. Also, spending to improve the quality is nonrecurring and results in long-lasting profits.

Furthermore, Dobrzyński and Waszczura (2012) stressed that, in the end, maintaining a 'hidden factory' considerably overrates the quality of production ('sigma' level). Therefore, it is imperative that companies become aware of this phenomenon. Figure 1 depicts the operation of a 'hidden factory.'

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Figure 1: Diagram depicting the operation of a 'hidden factory.'

The product is processed in the order in stages from 1, 2, 3, 4 to 5 (Figure 1). Figure 1 shows flaws detected at stage 3 with the product being returned from stage 5. This is usually performed without the knowledge and consent of management where the detected flaw is eliminated, and then the product is moved to position 6 where the final operations are carried out, and the control of the finished product is run. Such activities negatively influence production, and the company incurs additional costs because the time of production has been lengthened, while management is unaware of the disturbances occurring in the process. Nawrocki (n.d.) underlines that the 'hidden factory' does not improve production. Moreover, long-term, it becomes an integral part and is unnoticed by management, and thus, in turn, leads to wastefulness by the company. Identification of the 'hidden factory' phenomenon is relatively straightforward and is based on a comparison of classic and Six-Sigma derived yields. Thompson et al. Nieckuła (2005) revealed the weak aspects of classic yields, which usually appear after the occurrence of the 'hidden factory.' They are critical of the first-time yield, which does not include the number of flaws per selection unit nor the entire set of processes necessary to manufacture a product. Thompson et al. (2005) identified the superiority of yields from the Six Sigma method compared to that of the classic. The advantage is due to the former's selection method, i.e., counting flaws as well as faulty units. Also, Miller (2011) believed that the difference between rolled throughput yield and final yield should alert companies to the true efficiency of their operations, which is relatively low, and that their 'hidden factory' exaggerates the fulfilling of clients' expectations. Interpretation and functional dependencies of yield from both classic and the Six Sigma approach are described in Czabak-Górska and Lorenc (2015).

Data and Methodology

'Hidden Factory' Phenomenon – Case Study

The identification of the 'hidden factory' was carried out for a casting production line at Odlewnia Żeliwa S.A. in Zawiercie (Poland). This metal foundry specializes in producing iron castings, including connectors for water, gas and vapor installations, as well as minor machine castings. Production at the foundry consists of various stages (Figure 2). The production line operates on technology with mechanical extra-operational transport.

The results of the quality control documentation shown in Figure 2 formed the basis of the analysis. At each production stage there was a possibility of the following casting flaws that were listed as critical for quality: a fold or teeming arrest, dent, or burst (quality controls 1–3); precipitation, cold lap, or transposition (quality controls 1–3); and exterior bubble, ignition, or hot cracking (quality control 1).

Throughput yield denoted the probability of manufacturing all elements of a product in compliance with requirements. The normalized yield was the average of throughput yield expected at any stage of production. The yield (Y) denoted the probability of manufacturing all elements without a flaw.

Figure 2: Flow chart of the casting manufacturing process

Source: Authors

Figure 3: Control scheme by casting after the core, regarding quality, production phases

Source: Authors

Results and Discussion

Figure 3 compares incompatible products and other incompatibilities at every investigated stage. It also shows the yields, for throughput and rolled throughput. The remaining results are compared in Table 1.

At the beginning of manufacturing, the process planned to produce 2 365 units of castings (Figure 3). After manufacturing, the molds, pouring, and castings shake-out stage had 15 rejected pieces as waste products (i.e., defects unfit for further processing and subject to re-melting). At this stage, there were 395 pieces of castings that needed repair with a total 450 units detected with defects. Continuing operations, i.e., the finishing of castings and mechanical treatment of castings, involved 2 350 pieces. Quality Control 2 showed 10 units of castings needed repair and 30 had casting defects, without demonstrating the need to recognize any nonconforming unit. Then, after mechanical treatment of castings, none of the castings had defects, and there was no need for repair (Figure 3).

Table 1: Yields selected for the casting production

Classic yields		
First Time Yield		
▪ stage 1 (FTY ₁)		82.7%
▪ stage 2 (FTY ₂)		99.6%
▪ stage 3 (FTY ₃)		100.0%
Final Yield (FY)		82.9%
Yields of Six Sigma		
Defects per million opportunities (DPMO)		11 276
Yield (Y)		81.5%
Throughput yield (Y _T)		81.6%
Rolled throughput yield (Y _{RT})		81.6%
Normalized yield (Y _{NA})		93.5%
'Sigma' level		2.33

Source: Authors

The first-time yield (FTY₁) indicated that stage 1, preparing the matrix, potting, and striking castings, was the least efficient, from the perspective of fulfilling clients' expectations (Table 1). The probability that a product will pass a quality control in this first stage was 82.7%, which is 16.9% lower than that for the finishing stage. The results indicate 100% efficiency of the mechanical processing. The final yield showed that 17.1% of castings would not pass the quality control the first time. The number of flaws per million possibilities was 11 276 (Table 1), which is an extremely high value. In the three-sigma approach the 'perfection threshold' for defects per million opportunities (DPMO) is 0.002 and in Six Sigma method, 3.4.

The probability that a flaw would not appear in the product as a result of the process (Y) was 81.5%, which is a value close to the probability compatible with the requirements of manufacturing all elements of the product (81.6%). As well, it corresponds to a probability that the product, having passed through the entire process, will be without flaws (81.6%). The 'sigma' level was 2.33, which is an exceedingly poor result that leads to the conclusion that the process needs improving.

Comparing final yield (FY) with the rolled throughput yield (Y_{RT}) showed a 1.3% difference, which infers a 'hidden factory' in the process. Furthermore, the higher value of the normalized yield (Y_{NA}) of 93.5% compared to yield (Y) and throughput yield (Y_T) means that correction activities can be undertaken. This conclusion results directly from the definition of the indicators, which denote respectively: average expected as throughput yield at any stage of production (Y_{NA}), probability that processing would proceed without a flaw (Y) and probability of manufacturing all elements of a product in compliance with requirements (Y_T). Additionally, another concern is the activity of the 'hidden factory' with the relatively low 'sigma' level. In addition, the coexistence of the 'hidden factory' phenomenon with a relatively low 'sigma' level can cause that the efficiency of the production to be significantly inflated. As a consequence, the elimination of the "hidden factory" phenomenon without implementation of suitable strategies for improvement may result in a high percentage of defective product.

Conclusion

The problem of the 'hidden factory' in production facilities often ensues completely unnoticed by the management of the company. As the low to medium level managers, and particularly employees working directly on production lines, believe that flaws in production are a natural consequence of the whole process, such a phenomenon 'must' appear with regular frequency. At the same time, this personnel does not undertake appropriate activities aimed at improving the efficiency of the whole process. This study focused on identifying the phenomenon of a 'hidden factory' based on classic yields and those used in Six Sigma. The suggested yields were used to analyze production at a metal foundry in Zawiercie (Poland). The obtained results show the presence of a 'hidden factory' in the manufacturing of this company. As a way to improve the company's competitiveness, and at the same time, its financial gains, it is recommended the board of the company undertakes activities for maximum constraint of the 'hidden factory.' In particular, a situation where the running of production is characterized by excessive defects (high DPMO yield) and low efficiency (low 'sigma' level) indicates a borderline between an uncompetitive and competitive middle-class enterprise.

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