ARTIFICIAL INTELLIGENCE TO OPTIMIZE KEY FIGURES IN PRODUCTION

Martin Barth
University of Library Studies and Information Technologies

Abstract: The potential of the massive amount of data which is continuously recorded on the shop floor is only hesitantly and sometimes not fully exploited by the companies. Through the use of artificial intelligence, it is possible to optimize the key figures so that a much more realistic picture of the production is created. This is achieved by developing an artificial intelligence model for the realistic assessment of parameter values that influence the formation of a key figure.

Keywords: Artificial intelligence, key figures, shop floor, production planning, key performance indicators.

Introduction

With the headings Industry 4.0 and Industrial Internet of Things (IIOT), many companies are currently going through the so-called digital revolution [1]. The actual production data, which is used as raw data in the calculation of key figures, allows control of the processes. A core element for this is the visualization of the degree of target achievement on the basis of key figures. This allows for assessing the performance of the production teams, for jointly discussing improvement possibilities and for initiating optimization measures.

Shop floor indicators are calculated from various raw data. For most of them, in addition to the production data from the MES system used, data from other software tools not assigned to production are also included.

The production data, which is the focus of the consideration of the shop floor management, always shows the status of production. This is what production management focuses on and this data is in its direct sphere of influence. The administrative data such as set-up times, employee requirements, cycle times, raw material usage, often deviate far from reality.

Through the use of artificial intelligence, it is possible to optimize the key figures so that a much more realistic picture of the production is created. This is achieved by developing an artificial intelligence model for the realistic assessment of parameter values that influence the formation of a key figure.

The optimized key figures enable the company to make the key performance indicators more realistic in order to be able to initiate increases in performance based on reliable findings.

With advancing digitization, the manual and thus time-shifted data acquisition is getting replaced. A few years ago, under the catchphrase digitization, the conversion of analogue information into digital began. The data could suddenly be evaluated more extensively and, above all, more systematically. In return, the results helped to optimise the data collection and evaluation. This resulted in an ever-increasing wave of digital information procurement.

Key figures are often used to measure corporate management. They are used in many different areas of the company. The advantage of key figures is that they simplify complex issues and thus make them easier to understand and understandable for those who are not involved. Complex issues can be simplified to the respective needs to get a bigger picture or the level of detail can be adapted to the recipient's understanding of the processes. There are key figures that, formed by controlling, have become internationally recognized standard values. Such key figures serve as the basis for many official contacts or for communication with banks and authorities. If a loan is required for a company, key figures serve as a measure of the evaluation.

The application of key figures from a financial point of view runs through the entire operational process. Key figures are used to calculate whether the purchase of a new production machine is worthwhile, but also as a basis for determining the offer costs for a requested article [2].

By improving the quality of data with the help of artificial intelligence, the calculated key figures represent production much more realistically. Artificial intelligence is used on the basis of models. Once a model has been created, it can be used permanently for a non-changing production process. Therefore, it can also be used by non-experts without any problems.

Research methodology

Every company has its own key figures. This is particularly true in the shop floor area. In some cases, the key figures have developed over the years through many small stages to how they provide the optimal informative value for production. At other companies, key figures have been introduced by external consultants or service providers.

There are sometimes considerably different ways of looking at the formation of key figures. There is also hardly any agreement within an industry. Even manufacturers of the same products that are in direct competition with one another use different key figures on the shop floor.

The list of the key figures used by the companies alone, will only contain a few cross-company, evaluation-relevant elements. Therefore, the next step is to take apart the respective key figure. Each key figure is based on the principle of simplification. It is therefore necessary to know the time frame of reference for the key figure. A number like the OEE can be used flexibly in terms of time. This allows the current conditions to be displayed as well as the previous shift. The OEE can be used to compare the previous calendar week to the same calendar week in the previous year. This is not possible with other key figures. If the key figure indicates whether a profit can be achieved at all with the current material and manufacturing costs with fluctuating raw material prices, it cannot simply be reasonably formed over all arbitrary periods of time.

In addition to temporal classification, it is necessary to determine which raw data the key figure is made up of. Key figures often depend on one another. The key figures used for communication are often not obtained directly from raw data but consist of previously generated key figures. Such key figure systems are fed by very complex raw data. The consideration is completely detached from the data source used and the data quality. The aim is to identify all the initial data sources for the subsequent analysis. In the case of the raw data itself, care must be taken to include the references. Raw data such as the raw material price per kilogram, which applies to exactly one batch, must later be treated differently than an article sales price set over years. Another example is the energy costs, which usually fluctuate from year to year.

For the next step, the actual raw data is included in the analysis. First, the key figures are calculated as they are used in the respective company itself. If a key figure is used for several time periods, all uses are included in the analysis. For each calculated key figure, the raw data are now varied within the scope of their actual spread, which can be seen from the data pool. The bandwidth that occurs in each case is thus obtained for each key figure [3].

The problem is the raw data which is not generated from variable sources. Such a data record is e.g., the target cycle time. In contrast to the constantly changing variable values, e.g., number of good parts per shift and machine. The target cycle time does not change at all in many companies, or the adjustment only takes place every few months. In practice, there are considerable variations in the target cycle time. Here are some influencing factors:

- Raw material
- Media supply
- environmental conditions (Humidity, Temperature machine hall, Temperature of raw material)

All of the points listed influence the cycle time. But there is only one value in the ERP system for the cycle time which cannot reflect the different conditions [4].

Just like the cycle time, there are many other influencing factors or raw data whose fluctuations have a direct influence on the key figures, but do not allow any variation due to their origin. This could be, for example, the costs per manpower hour, which in the link to the HR tool can only flow into the key figure as a fixed specification as averaged costs. As part of the analysis, the values with such errors need to be established.

Artificial intelligence optimization model

If you want to get to the bottom of a situation or problem with the help of artificial intelligence, it is important to proceed in a precisely structured manner from the start. The general view is that the use of artificial intelligence always entails a large project with many participants and even more money. The application is not as complicated and not as expensive as expected. The use of AI can be divided into 5 steps. As with every KPI project, shop floor management begins with the selection of the use case. This is followed by the acquisition and preparation of the data. The first point that deviates from a non-AI project is the creation of the AI model. The training of the model also takes place at the same time as it is created. An important point before the final use is the validation of the model. So the comparison of the AI with a known, already completed scenario. It is therefore checked whether the AI model used to predict an already real situation corresponds to the one that occurred.

Step 1: Selecting the use case

At the beginning, the most important thing is to make it clear exactly which problem is to be solved specifically with the help of the use of AI. First of all, it is advisable to start with a smaller, precisely defined use case. It is easiest not to start immediately with an all-encompassing project, but it is much easier to establish an AI model on a small scale and then expand it.

As a further important point, the planned goal is set in advance. So which forecast should be made or which decision-making basis should be underpinned.

The company data used for the analysis come from automotive series suppliers who have been using established key figures for planning production and for decision-making in optimizations for years.

In order to determine the accuracy of a key figure, it must be analysed in detail. This is done by breaking down the key figure into its calculation bases. These principles are in turn based on raw data. A detailed examination of the origin of this raw data allows initial conclusions to be drawn about the quality of the entire key figure. In the next step, the raw data is changed within the typical fluctuation range. This gives the degree of inaccuracy. This manual process is extremely time consuming. At the end of the day there is still the problem: what to do with the knowledge gained. The systems do not offer the option of entering dependent raw data. The use of artificial intelligence enables both a statement about the improved accuracy and also an automatic filing of the knowledge gained. This means that the model can be used again immediately and on the basis of the latest findings.

The key figures of packing performance and employee productivity are used for the preliminary investigation.

The key figure packing performance per staff hour is used to assess the effort required for a production order. This makes it easy to assess whether an item causes problems or whether it is not worth manufacturing.

$$Packing\ performance\ per\ staff\ hour = \frac{(Yild\ x\ weight)}{Occupancy\ time}$$

Table 1 Key figure packing performance for 3 production orders

Order	Good quantity	Article weight	Occupancy time	Packing performance
FA 144751	10.261	18 g	246 h	**2,27**
FA 14586	4160	18 g	95 h	**2,37**
FA 14604	12.426	18 g	310 h	**2,18**

Data origin and expected fluctuations:

– Good quantity → real data from MES → no fluctuations

– Article weight → ERP system → high inaccuracy

– Occupancy time = cycle time (from ERP) x (yield) → together high inaccuracy

Data fluctuations / inaccuracy:

– Item weight:

The article weight is used from the ERP system. There is only one target specification – no actual or actual comparison.

– The occupancy time is calculated from the cycle time stored in the ERP system times the yield. Since the cycle time is subject to high fluctuations, the occupancy time is very imprecise.

Optimization potential through AI:

The mean article weight can be defined very precisely and anew for each order using the calculation from the worker self-test with the aid of AI.

The occupancy time with the problem of the cycle time from the ERP system can be significantly improved by AI.

The employee productivity shows with how much effort in personnel hours what amount of raw material was processed. The key figure is typical for a plastics processor. Very high material throughputs are generated here so that the key figure is highly informative. It is not suitable for low material throughput. works well. The key figure is calculated on the basis of the shift, week, month, calendar year, each with a comparison period.

$$\text{employee productivity} = \frac{\textit{Material throughput}}{\textit{Hours of all production workers}}$$

Table 2 Key figure employee productivity per shift

Date - Shift	Material throughput	Employee time	Employee productivity
08.03. 2021 – Shift 1	2.400 kg	67,2 h	**36**
08.03. 2021 – Shift 2	2.900 kg	62,4 h	**46**
08.03. 2021 – Shift 3	18.00 kg	48,0 h	**38**

Data origin and expected fluctuations:

– Material throughput per time unit (shift, week, etc.) → real data from MES for the number of articles. Article weight from ERP with large fluctuations; Start-up scrap is not included

– Hours of all production employees → real data from HR → no fluctuations

Data fluctuations / inaccuracy / optimization potential through AI:

– The material throughput per shift, week, etc. is calculated from the raw data for the number of items (good and bad parts) times the weight of the item. The article weight is managed with a fixed value in the ERP system. Given the high throughput, a small fluctuation has a huge impact. The start-up committee is completely disregarded, but it can also very quickly become a lot of material. Both values can be recorded or improved with AI.

Step 2: Acquisition and pre-processing of the data

The most important step is to obtain the basic data. The key here is to collect the right data. The quality of the results depends to a large extent on the quality of the raw data used. The use of AI cannot work miracles and deliver top results from inaccurate or incorrect basic data. In most cases, the greatest amount of time is required to obtain data.

The first question is which data is available at all. Often data from different sources can be used. In order to get an overview, it helps to define influencing factors and to classify the origin of the data accordingly. For the use of the AI, it is irrelevant how many initial sources contributed to the solution in the end. Here, too, it is important that the data quality is ensured for the respective source. In practice, it is not always easy to have an overview of the reliability of the data from all systems. Often the users trust the systems blindly and do not question the values, especially when systems have been implemented by external parties and there is no in-house contact person. In manufacturing companies, this most often applies to HR software. Due to data protection regulations, not many people are allowed to have access. Those who are allowed to do so are often only the users themselves – no IT experts or process owners.

The data must be prepared for the AI application in such a way that they are easy to use and evaluate by the AI. Here, too, it is recommended to work with only a few parameters at the beginning and, if successful, to carry out model extensions instead of working with too many parameters at the beginning and to be able to narrow down the reasons only with difficulty in the event of problems.

Manufacturing data from several companies from series production could be used for the investigation. The data made available are the unadulterated raw data of the companies.

Step 3: Creation and training of the AI model

When creating an AI model, it is a matter of transferring the processed data to the AI in one process, assessing the results and, depending on the result, revising the data and starting again. This training process can be repeated several times and it also quickly becomes apparent if the raw data used is not of sufficient quality. First of all, not all raw data should be included. If around a fifth to a quarter of the data is retained, it can be used for validation. If all data are in the model from the start, the results must be trusted without testing. The AI recognizes patterns and dependencies in the input data. Once brought into the model, the data is practically used up. Because data that has been entered for training can no longer be used to check the quality of the output.

Step 4: validating the model

Validation means "checking the data for compliance with certain previously established validation rules"[1]. This is exactly what has to be done in step 4. It is checked how successful the training was for the performance of the AI. In this way, it is possible to classify how applicable the AI model will be for productive use. During the validation, the results are carefully examined and compared with reality. It makes sense to define the assessment rules precisely. This leaves little room for interpretation when classifying the results. The validation is carried out using the previously withheld data. These are entered into the trained AI. The results or the statements based on the data previously unknown to the AI can now be compared with the actual numbers. If the comparison shows an unexpectedly large discrepancy, the entire process must be restarted from the beginning, of course with changed conditions, e.g., qualitatively better raw data. If the validation shows a successful result when considering the previously established rules, e.g., if the prognoses are correct, one can assume that the application will be successful when applied in production.

Step 5: Be productive

The AI model is now ready for use in production. The trained model can be used for the trained scenario without further control. The AI also offers the possibility of expanding or further improving the model. All you have to do is repeat the previous steps as soon as new data is available. In order to be able to react to changed boundary conditions or new findings, it is advisable to proceed at regular intervals. In this way, the model is continuously optimized, kept up-to-date and therefore more precise.

Results

In order to be able to evaluate the improvements through the use of AI, the result is compared with the actual reality. Only half of the existing data is used for AI optimization. With the second half, the reality is compared with the original plan. Once with AI use and once without. This analysis method shows clearly and easily understandable the existing potential for improvement. The disadvantage of this method is the limitation of the data to the fluctuations that occurred by chance during the observation period. The actually possible potential remains undetected. If the person who creates the plan knows before that the plan will be used as a reference, he will proceed much more conscientiously than he normally does.

For the packing performance key figure, the graphic shows that the calendar weeks 14 to 30. Weeks 14 to 21 were used to create the model of the AI. The height of the bar describes how many percent deviation is between the planning and the reality.

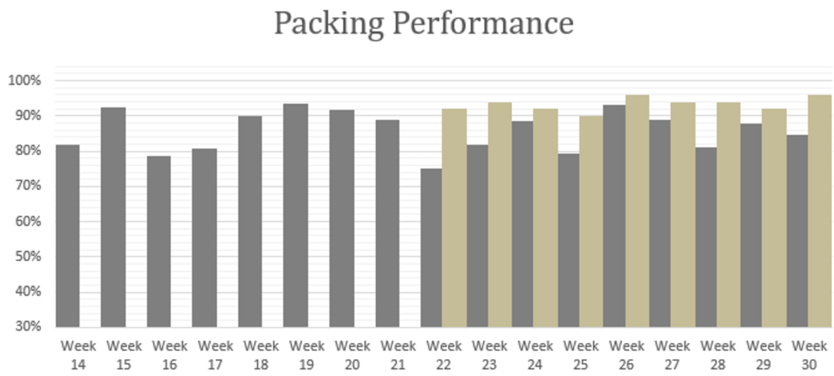

Fig. 1 Packing Performance in percentage (with and without AI use)

In week 14 the bar shows 82 percent. This meant that the planning was 18 percent off the mark. Weeks 22 to 30 show, in dark gray, the actual situation that has occurred. The light gray bars next to it show which deviations would have occurred if the planning had behaved with the help of the model developed, in weeks 14 to 21. The differences are very clear. In some weeks, the AI planning was 8 percent off. Manual planning 24 percent.

The employee productivity figure shows a similar picture. The use of AI has ensured that productivity has increased across all shifts. For this graphic the AI model was initially created from May 10th to May 12th over 3 shifts. In the following days, you can see the comparison of the reality that has arrived with the one calculated from the AI. There have also been very significant improvements in this key figure.

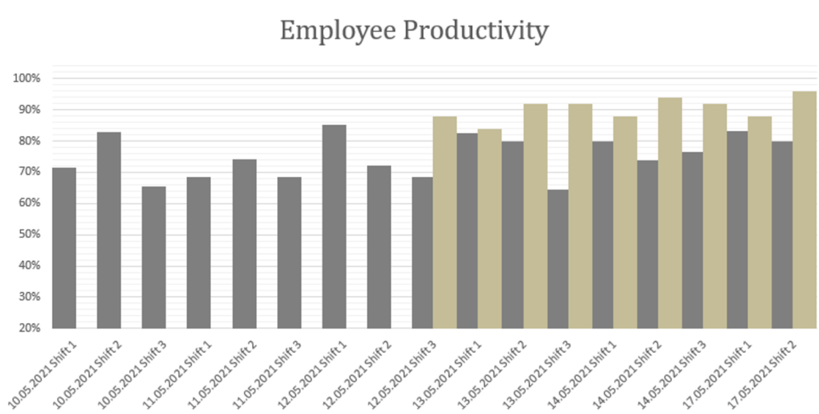

Fig.2: Employee Productivity in percentage (with/without AI)

The use of artificial intelligence to optimize key figures on the shop floor offers considerable potential for improvement in planning. The results show that the use of artificial intelligence is very well suited for optimizing manufacturing processes. The use of artificial intelligence makes undetected dependencies within the manufacturing processes transparent. This allows problems and dependencies to be found and removed from the way.

Conclusions/discussion

With the help of Artificial Intelligence, the basis of decisions in manufacturing can be significantly improved. The potential for application scenarios is huge. Since every company uses its own processes, plans and decision-making paths, the use of artificial intelligence cannot be installed in a predefined manner, but rather has to be carried out individually.

The decisive criterion for successful use is the quality of the output data. A “sloppy” data management sort also for a low probability of applicability. This means that the basic problem of any key figure system remains. The employees have to record the data conscientiously and with the best possible accuracy.

The biggest criticism of the use of artificial intelligence in society is the ethical discussion about whether decisions are 'allowed' to be made by machines. This point of criticism is not relevant for the use to improve key figures in the production environment because the use only improves the output data and does not operate any switches.

For the company, the question of the effort involved in implementation and operation remains. A model generated with the help of artificial intelligence can always be used as long as the process does not change. Since the purpose of the application is precisely such changes and optimizations, the model must also be constantly adapted. Many companies shy away from the personnel costs required for this as well as the support costs that are often outsourced.

Key figures are generated for every manufacturing company. With the help of these key figures, planning is as realistic as possible. Due to the large number of influencing factors, it is very difficult to calculate the key figures in such a way that they reflect the actual reality. Manual optimization methodes to improve the collected data are very complex. The data is to collect without knowing whether the data is even relevant to improve the key figures. Due to this problem, the use of artificial intelligence to optimize key figures on the shop floor is a good idea. The existing social concerns associated with the use of artificial intelligence can be left aside in the manufacturing environment.

Artificial intelligence can be used very well to optimize key figures in the manufacturing environment. It offers high potential for increasing the productivity of manufacturing companies. It could be shown that by using the AI, improvements in production planning of up to 20 percent are possible. Reasonably integrated into existing key figure systems, the deployment can be carried out with negligible personnel expenditure.

The use of artificial intelligence is not limited to the use to improve planning. The big amount of dependencies in the manufacturing environment offer a wide range of possible uses. This can also apply to machine maintenance, for example. Or also the energy optimization of the systems.

Notes

[1] Stefan **Luber**, Nico **Litzel**. Was ist Validierung? // Bigdata insider. 21. November 2019. https://www.bigdata-insider.de/was-ist-validierung-a-884683/ (12. Aug. 2021).

References

1. **Minssen**, Heiner. Industrie 4.0: ein Strukturbruch? Hoose, Fabian; Beckmann, Fabian; Schönauer, Anna-Lena. Kontinuität und Wandel von Wirtschaft und Gesellschaft. Springer. 2017. Pages 117–135.
2. **Horváth** & Partner. Früherkennung in der Unternehmenssteuerung, Stuttgart: Schäffer-Poeschel Verlag, 2000. Page 568f.
3. **Peters**, Remco. Shopfloor-Management: Führen am Ort der Wertschöpfung. Stuttgart LOG-X. 2017. Pages 86-88.
4. **Hessler**/Görtz. Basiswissen ERP-Systeme: Auswahl, Einführung & Einsatz betriebswirtschaftlicher Standardsoftware. W3L Herdecke. 2008. Page 61

About the author

Martin Barth, 44 years old, engineer and Master of Science has worked in product management for a manufacturer of MES standard software for more than 7 years. His current doctorate is with the topic 'Optimization of Shop Floor Indicators through the Use of Artificial Intelligence' at ULSIT Sofia.

To contact the author: barth_martin@web.de