Assessing Process Maturity of an Underground Mine: a Case Study

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Abstract

Business process management is now the most dynamically developing concept in organisation management. In order to further improve process efficiency, it is advisable to analyse the current situation and determine the position of the organisation in terms of its progress in implementing the process approach. This is where the evaluation of the organisation's process maturity proves useful. And the available literature provides an array of models for such assessment.
This paper presents the results of a process maturity study for a selected hard coal mine based on the Capability Maturity Model Integration (CMMI) framework. The mine was ranked level 3 in process maturity, which is on a par with other Polish businesses. This score suggests opportunities for further improvement towards a more process-oriented business approach.

Keywords: process maturity, business process management, coal mine, process maturity models

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Introduction

Recently, and especially during recession, mining companies owned by the Treasury have taken various steps to improve their performance. These included, inter alia, management process enhancement, production structure optimisation, and cost reduction (see Informacja o funkcjonowaniu..., 2015).

The performance of those businesses can generally be improved by enhancing the efficiency of their processes. This is where the potential is for some measurable benefits, in both production and finance.

All mining businesses employ Integrated Management Systems, which rely on the process approach (as per the ISO standard), but it is important to note that these organisations are not managed through process management.

In order to further improve process efficiency, it is advisable to analyse the current situation and determine the position of the organisation in terms of its progress in implementing the process approach, especially in relation to the processes implemented in production units (mines). This is where the evaluation of the organisation's process maturity proves useful. And the available literature provides an array of models for such assessment.

The article is structured as follows: the first part of this paper outlines the business process approach. In Section 3 selected business process maturity assessment models are presented. Section 4 presents the results of a process maturity assessment for a selected mine. Finally, summary and conclusions are presented in Section 5.

An outline of the business process approach

Processes were employed already in the early 20th century to analyse organisational performance. At first, however, this was only to assess production systems (Grajewski 2016). The true explosion of interest in processes, as fundamental business components, took place in the late 20th century as a result of the exploration of business process reengineering, a concept developed by Michael Hammer.

The theory of management uses various definitions of a process, both general and detailed. Selected definitions are presented in Table 1.

What all these definitions have in common are the recurring characteristics attributed to processes, namely that these are sets of specific actions designed to achieve a common goal (a product, a service or an output that is of value to the customer).

A process is defined by external and internal elements (Krawczyk, 2011). The internal elements include the entity that is the potential or actual beneficiary of the process output, and the resources and assets necessary as process inputs. Internal elements include process activities, place and equipment necessary to perform the activities, and personnel.

Each process involves the consumption of specific resources. At the same time, it is a value chain, in which each activity should add value to the results of previous activities. All these claims suggest a direction for designing processes to facilitate a maximum increase in product or service value while using minimum resources. Therefore, an organisation is as efficient as are its processes (Łunarski, 2014).

Business processes create a process system, i.e., a set of interconnected activities which transform system inputs into system outputs. The system is characterised by the relationships between processes and the mutual links between the inputs and outputs of each process.

Tab. 1. Selected definitions of a process
Tab. 1. Wybrane definicje procesu [Source: own work]

Author(s)	Definition	Source
Hammer M., Champy J., 1996	A business process is a collection of activities that takes one or more kinds of input and creates an output that is of value to the customer.	Reengineering w przedsiębiorstwie. Published by Neumann Institute, Warsaw, p. 49
Manganelli R.L., Klein M.M., 1998	A process is an interrelated series of activities that converts business inputs into business outputs.	Reengineering. Metoda usprawniania organizacji. Published by PWE, p. 27
Grajewski P., 2007	A process is a sequence of activities which transform measurable inputs (materials, information, people, equipment, methods) into measurable outputs (products, services, information).	Organizacja procesowa. Published by PWE, Warsaw, p. 55
Skrzypek E., Hofman M., 2010	A process is a sequence of activities taken to convert the initially available resources and information into products, thus creating added value for the customer (whether internal or external)	Zarządzanie procesami w przedsiębiorstwie. Oficyna Wolters Kluwer business, Warsaw 2010, p. 19
ISO 9000:2015 (EN)	Set of interrelated or interacting activities that use inputs to deliver an intended result	p.15

All disruptions or discontinuities at the interface of even a few processes make the process system less efficient, affecting the efficiency of resources used in such processes (Skrzypek and Hofman, 2010).

The process approach to business is based on the assumption that activities need to be optimised by taking into account processes, not functions. This covers the processes implemented by the business (process organisation), as opposed to classic structures where functions are performed by specific divisions, departments or organisational units (functional structure). Indeed, processes usually go beyond organisational borders (Kuchta and Ryńca, 2007).

The process approach reorganises the internal structure of the whole business by both redesigning the processes (in terms of value creation) and by redefining the functions of the existing units included in the organisation. The fundamental principle in process organisation is to assume that each organisational area is an internal customer and at the same time an internal service provider for other areas. Such internal service providers can be grouped into service centres, cost centres and profit centres (Grajewski, 2016).

What is characteristic of process organisation is the flattening of the organisational structure and the departure from a clear division of roles and the traditional system of relations based on a rigid division of responsibility. It emphasises the importance of team work and teams responsible for process implementation. New positions appear, including those of process owner and process manager.

The primary elements of the business process approach include:

- process goal identification,
- process identification,
- process measure identification, and
- identification of activities and responsibilities of each unit within the process system.

It is crucial for business performance to identify process goals, as they capture what the process system should implement and to what extent. These goals build on strategic objectives for process owners (these are operational goals which are made more specific at the level of organisational units or activities taken within processes) (Skrzypek and Hofman, 2010). It is vital for the system of goals in a business to be coherent (at each level, i.e., strategic, tactical, and operational) and to not repeat the same, or have mutually exclusive, process goals.

The following approaches can be adopted to identify processes and create process maps (Kwieciński, 2014):

1. top-down, where the general business of the organisation is outlined, and then the identified elements are made more specific; core processes and their respective activities are identified first, and support processes later,
2. bottom-up, where the activities performed within the organisation are analysed to formulate the processes,
3. inside out, which in a way builds on the top-down approach, as it starts with defining key processes in considerable detail, and then proceeds to identify further processes, sub-processes, and supporting measures,
4. mixed, which combines the above-mentioned approaches to achieve optimum results and process mapping.

Process maps make it possible to analyse the current state of business processes and constitute the basis for further process improvements.

When process mapping is completed, appropriate measures are selected for each process. These measures should facilitate, i.a., efficiency measurement,

Tab. 2. Business process maturity levels in CMMI
Tab. 2. Poziomy dojrzałości procesowej organizacji w modelu CMMI [Source: own work on the basis of (Harmon, 2016)]

Level	Description	Characteristics
1	No processes organised	The organisation does not operate on the basis of processes. The organisation is based on individual heroic efforts. There are no systematic procedures to answer questions concerning task duration or necessary resources.
2	Some processes organised	The business is not conceptualised as a set of interrelated processes. The organisation focuses on selected (core or most commonly used) processes and how they function within some specific boundaries. The organisation has several of its major processes defined.
3	Most processes organised	The organisation has most of its processes defined. It not only has models of its core business processes, but also understands how support and management processes work to support those processes. The organisation has process maps to easily identify any processes that cause problems and suggest changes.
4	Processes are managed	The organisation has gone far beyond defining all its processes. The organisation has process managers who gather data on process performance and customer satisfaction. These data are used to make decisions about how to optimise the processes they manage.
5	Processes continuously improved	Processes have been built right into the essence of the organisation. The organisation knows its processes and manages them. Moreover, it has appropriate systems in place to continuously improve its processes whenever possible.

and capture the results of any implemented improvements (using Key Performance Indicators, KPI). These measures include, for instance, average order delivery time, product design time, number of complaints, and production department efficiency. Each measure has to specify, among other things (Skrzypek and Hofman, 2010), the measurement unit, target values, measurement frequency, data source, and the person responsible for process results and reporting.

The final step is to specify the powers and scope of activities for each business unit. In the process approach, process management is the responsibility of the process owner, and its implementation is carried out by the relevant team.

Usually, the existing organisational structure is transformed into a process structure by grouping process performers into process teams, which are included in the same organisational units, the manager of which generally becomes the process owner (Skrzypek and Hofman, 2010). Some other solutions are possible, too (see, e.g., Grajewski, 2016).

In the literature there are two major concepts that explore process management. The first involves the continuous and systematic implementation of process changes and improvements (Business Process Improvement, Deming cycle – Harrington, 1991); while the second is about process reengineering (usually understood as a radical and comprehensive redesigning of business processes – Business Process Reengineering – Hammer and Champy, 1996). In addition to those mentioned above, it seems important to note other existing business process management concepts, such as

- Process innovation (Davenport and Short, 1990),
- Business process redesign (Burke and Peppard, 1993),
- Business process management (Lee and Dale, 1998).

Tab. 3. An overview of selected process maturity models
Tab. 3. Charakterystyka wybranych modeli dojrzałości procesowej [Source: own work on the basis of (Roeglinger et al., 2012)]

Model	Year	Lowest maturity level	Upmost maturity level
Process Maturity Ladder (PML)	2004	**Initial:** Processes are not defined.	**Optimising:** Processes are measured and managed. Process improvement teams exist.
BPO Maturity Model (BPOMM)	2007	**Ad hoc**: Processes are unstructured and ill-defined. No process measures exist. Organisational structures are based on traditional functions.	**Integrated:** The organisation cooperates with vendors and suppliers on process level. Organisational structures are based on processes. There are deeply embedded process measures.
Process and Enterprise Maturity Model (PEMM)	2007	**P-1/E-1:** Processes have not been defined on an end-to-end basis. Fragmented legacy IT systems support processes.	**P-4/E-4:** Process design fits with customer and supplier processes. Modular IT architecture exists.
Business Process Maturity Model by Weber (BPMM-OMG)	2008	**Initial:** There is "fire-fighting management". Success depends on the competence and heroics of individuals and not on the use of proven processes.	**Innovating:** There is "change-management". Approaches to defect and problem prevention as well as continuous and innovative improvements are in place.
Process Management Maturity Assessment (PMMA)	2009	**Initial:** Processes are not defined; success depends on certain specialists; schedule, quality and costs are not predictable.	**Optimising:** Processes are analysed, optimised and adjusted to changes in market requirements systematically. Benchmarking and mistake avoidance is pursued.

All of these concepts to some extent involve elements of small or large changes in business processes.

Mining processes, especially in underground mines, have been investigated by many scholars, including Zając (1992), Musioł (1990), Lisowski (2001), Korski (2005), Kostka and Kowal (2014). Their works provide different definitions and classifications of the processes implemented in underground mines. However, despite the considerable interest in the structure itself and in the mining process, there have been few publications on the process approach in hard coal mines. One such publication is a work by (Korski and Korski, 2015), which proposes a general model of the process system in an underground mine. A work by (Burchardt et al., 2016), too, identifies and classifies core and support processes in a hard coal mine for environmental LCA assessment purposes.

The newest approaches related to process definition, modelling and analysis in underground mining include process flow simulation in a longwall face (Kęsek et al. 2019) and process mining based on event logs from longwall monitoring system (Brzychczy E. and Trzcionkowska A. 2019).

In order to implement the ISO standard, coal companies have developed process maps and described the procedures (processes) they implement, but, unfortunately, they have introduced process-based management only to a small extent. An attempt to assess process management on the basis of a selected hard coal mine is made later on in the article.

Business process maturity assessment models

Process maturity corresponds to the extent to which processes are formally defined, managed, flexible, measured and efficient within an organisation (Grajewski, 2016).

The idea to assess process maturity levels emerged at the Software Engineering Institute (SEI), Carnegie Mellon University, in the 1990s, and was the brainchild of Watts Humprey (Humprey, 1988). Initially, the developed Capability Maturity Model (CMM) was intended to analyse the maturity of software development processes. But its latest version, Capability Maturity Model Integration (CMMI), has been made more general so that the model can be applied to assess process maturity in various organisations (Harmon, 2016). In this model, process maturity assessment refers to five levels, which are described in Table 2.

In addition to the model described above, the literature provides other business maturity assessment models, including those applicable to processes. An overview of selected process maturity models is presented in Table 3.

These models largely (except only for PEMM) rely on five-level scales. They are characterised by vary-

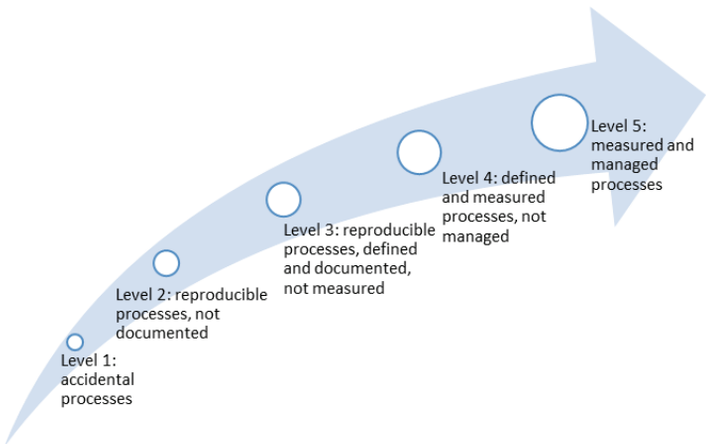

Fig. 1. Process maturity levels [Źródło: Dojrzałość procesowa polskich organizacji]
Rys. 1. Poziomy dojrzałości procesowej [Source: own work on the basis of Process maturity of Polish organisations]

Tab. 4. The frequency of process maturity assessments for a selected mine
Tab. 4. Tabela liczności ocen dojrzałości procesowej wybranej kopalni

Assessment	Number of answers	Percentage	Cumulated percentage
1	0	-	-
2	6	16.7	16.7
3	26	72.2	88.9
4	3	8.3	97.2
5	1	2.8	100.0
Total	36	100.0	

ing levels of detail and complexity, from rather simple, such as PML, to more complex ones, like PEMM and BPMM-OMG. As you might notice, there is some similarity between the characteristics defined for specific maturity levels (c.f., PMMA and BPMM-MOG or BPOMM and PML). Some models build on CMMI in their maturity levels.

A certain generalisation of CMMI was also used in the latest study of selected organisations in Poland (Dojrzałość procesowa polskich organizacji [Process maturity of Polish organisations], 2016). In that study, organisational maturity levels were related to the degree to which processes had been documented, defined, measured, and managed (Fig. 1).

Having interviewed 236 respondents from various provinces in Poland, the study authors showed that the highest (fifth) level of process maturity was found in only 4% of the studied organisations, and 28% were at the fourth level. The largest number (37%) were at the third level of process maturity.

These findings are not very different from the trends observed worldwide. The majority of US organisations rank between the second and third levels of maturity. In large organisations individual units can often be observed to differ in this level (Harmon, 2016).

A recent study carried out in Poland in relation to small and medium-sized enterprise (Okręglicka et al., 2015) showed that process maturity levels varied across different areas of those businesses, i.e., production, marketing and sales, HR, finance, and risk management.

In relation to processes in mining companies in Poland, a qualitative maturity study was carried out into natural aggregate mining (Łukasiński, 2016). That study also used a five-level scale. The mean value for the qualitative maturity of the identified processes was 3,23.

Process maturity assessment of a selected hard coal mine

The mine selected for analysis is based in Upper Silesia. It is part of a multi-plant enterprise with a diverse product portfolio. The company had implemented an Integrated Management System with a Quality Management System compliant with ISO 9001 and ISO 14001 standards.

The process maturity assessment of the selected mine was carried out using a survey based on CMMI (Table 2).

The survey examined 36 people (4 women and 32 men). Respondents' characteristics are presented in Figures 2–5.

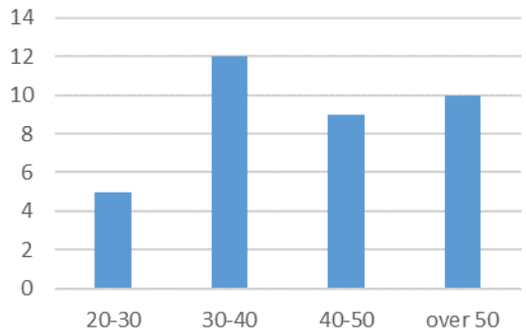

Fig. 2. Respondents' age
Rys. 2. Wiek ankietowanych

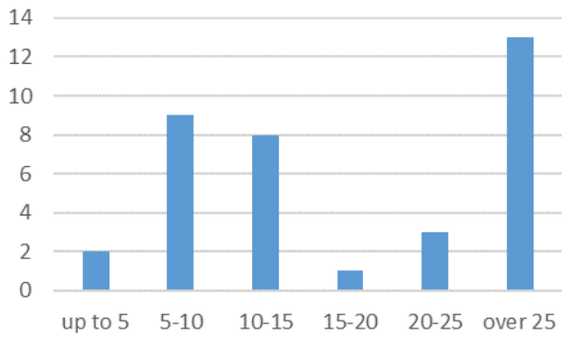

Fig. 3. Respondents' work experience
Rys. 3. Staż pracy ankietowanych

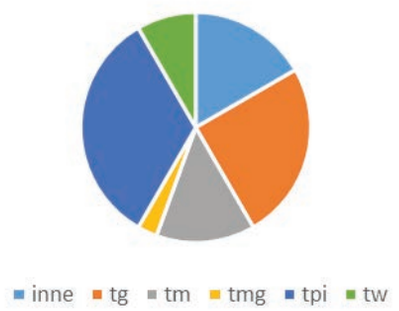

Fig. 4. Respondents' department
Rys. 4. Dział zatrudnienia ankietowanych

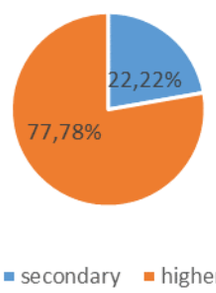

Fig. 5. Respondents' education level
Rys. 5. Wykształcenie ankietowanych

The majority of respondents were aged 30+. Most of them were experienced employees, with more than 25 years of work experience (13 persons). The respondents were employed in various departments, including investment project preparation (tpi), power machinery (tm), survey and geological (tmg), ventilation (tw), mining (tg), and other. More than 77% of respondents (28 persons) had higher education.

Respondents' answers are presented in Table 4 and Figure 6.

Overall, the assessment by CMMI shows that the selected hard coal mine can be classified at level 3 of process maturity (weighted mean was 2.97), and a substantial majority of respondents (72%) chose this level as corresponding to the actual situation in the analysed mine. This means that they were aware of the impact of individual processes on one another, and of the fact that company performance depended on successful cooperation between different units. The company has its individual processes described (prepared during the implementation of ISO 9000) and its measures defined. Unfortunately, given the circumstances in the analysed mine, appointed project owners usually have no real influence over the processes and their implementation. Moreover, in some cases the defined measures did not refer to the achievement of process goals.

This survey of process maturity provides a general overview of process management in the selected mine. The next step we plan to take is to carry out a study of the maturity of selected processes using PEMM (Hammer, 2007), a model that facilitates a more comprehensive assessment and evaluation of analysed processes across several areas, i.e., design, performers, owner, infrastructure, and measures. Under PEMM, process maturity assessment is conducted on the basis of a detailed table presented in (Hammer, 2007). The results of that study will be presented in future publications.

Summary

Without doubt, the success of any organisation relies on efficient processes. When flexible and well-managed, they can provide the business with competitive advantage.

Businesses very often say they employ process-based management. Unfortunately, this is not confirmed in their process maturity assessment. Usually, it turns out that the actions they take are superficial and limited to the development of process maps and defining measures, without utilising the collected information to optimise the processes. Process management is perceived to be an addition to classic management of the organisation with a functional structure, and the created documentation (including process maps, procedures, and measures) is usually intended to help the organisation obtain some certification.

This article presented the results of a general process maturity assessment in a selected underground

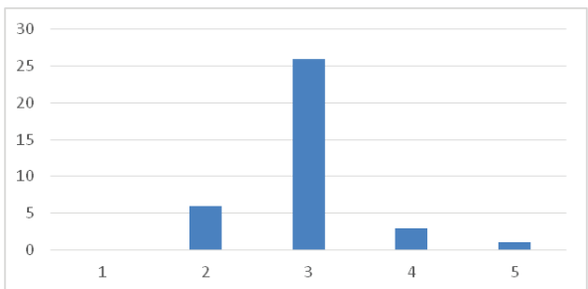

Fig. 6. A histogram of process maturity assessments for the selected mine [Source: own work]
Rys. 6. Histogram ocen dojrzałości procesowej wybranej kopalni

mine. In the survey based on CMMI, the hard coal mine was assessed to have level 3 process maturity (the weighted mean was 2.97), and a substantial majority of respondents (72%) chose this level as corresponding to the actual situation in the analysed mine.

The situation in the analysed company is comparable to the performance of other Polish companies (c.f., Dojrzałość procesowa polskich organizacji [Process maturity of Polish organisations] 2016). On the other hand, however, this assessment suggests opportunities for further improvement towards a more process-oriented business approach. The management actions taken by such companies should focus on the evolution of their organisational structures and continued enhancement of their processes, which show potential for improved performance of mining companies.

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Ocena poziomu dojrzałości procesowej kopalni podziemnej na wybranym przykładzie

Zarządzanie procesami biznesowymi jest obecnie najbardziej prężnie rozwijającą się koncepcją w zarządzaniu organizacjami. Do dalszych działań mających na celu zwiększenie efektywności procesów warto jest dokonać analizy stanu obecnego i określenia miejsca, w którym faktycznie znajdują się przedsiębiorstwa w zakresie wdrożenia podejścia procesowego. W tym celu można wykonać badania poziomu dojrzałości procesowej organizacji, w oparciu o dostępne w literaturze modele.
W artykule przedstawiono wyniki badań dojrzałości procesowej w wybranej kopalni węgla kamiennego z wykorzystaniem ogólnego modelu CMMI. Kopalnia została oceniona na 3 poziomie dojrzałości procesowej, co nie odbiega od ogólnej oceny innych polskich przedsiębiorstw. Uzyskany wynik świadczy także o istniejących możliwościach dalszych prac w zakresie reorientacji organizacji na procesy.

Słowa kluczowe: dojrzałość procesowa, zarządzanie procesami biznesowymi, kopalnia węgla kamiennego, modele oceny dojrzałości procesowej