Process mining in support of technological readiness level assessment

Veneta Markovska¹*, Stanimir Kabaivanov²

¹ University of Food Technologies, Plovdiv, Bulgaria
² Plovdiv University “Paisii Hilendarski”, Plovdiv, Bulgaria

* venetta@abv.bg

Abstract. We develop a framework for assessing technological readiness level using available data on business processes. By constructing a network of actors and linking process steps together it is possible to estimate the complexity of organizational structure, examine the bottlenecks and analyse whether advantages of available technology are fully utilized. Using publicly available data on business event logs we also test an automated process mining procedure and suggest a measurement to link our results to the TRL.

1. Introduction

Since its first steps in NASA in 1974 [1], technological readiness level (TRL) has gone a long way to become a wide spread tool for assessing adoption of new concepts and use of existing ones. Based on general, yet sound principles, it has proven to be useful tool for supporting management decisions [2], [3], as well as for assessment of innovations [4], [5]. Considering that some concepts may be more complex than others, the TRL research has been carried on to extend original classification, either by adding new levels [6] or by transforming it into a performance matrix [7]. While there is still an ongoing debate on advantages of specific extensions of the idea in different industries, it is particularly important for practitioners to have a reliable tools supporting their assessment. Due to the fact that real businesses need to take decisions under uncertainty and considering multiple factors that may not be explicitly taken into account in academic research, it is vital for these tools to be flexible.

Quite common approach for assessment of technological readiness is to conduct a survey with carefully selected questions and based on the answers to assign respondent descriptions to a set of predefined categories. Despite being a straightforward process, this method has several significant drawbacks:

- The number of respondents in a survey may be limited, based on the organization structure, as well as the complexity of the problems addressed. Trying to assess a technologically diverse organization with a limited data set is very challenging and error prone.
- Business processes tend to have different scalability properties which means that similar TRL assessments may end up with a completely unrelated results under modified environment conditions.
- Non-linear relationships between different processes and steps in the organization performance have to be taken into consideration.


We believe that careful analysis of business processes could help improve technological readiness assessment both in terms of required efforts and reliability of final output. Dependencies between business process understanding and TRL has been subject to multiple studies, like for example [8], [9]. Instead of building on a predefined and limited assumptions on the processes, we suggest to analyze information on procedures in the organization in order to build a map of current processes and inspect their complexity and depth. There are a lot of algorithms, aiming at automated business process discovery (ABPD), that offer a tradeoff between speed and accuracy [10], [11]. In this paper we use precedence and activity matrices in order to analyze business processes and then apply metrics that can assess their complexity. TRL and process analysis are important for non-business organizations [12], [13].

2. Model details

The model as shown on Figure 1, consists of five steps, that need to be repeated on demand or periodically in order to account for changes in the environment and internal organization. It should be pointed out that these five steps can be used with different TRL metrics and risk measures as well as with different complexity assessment procedures.

A sequence of events would typically contain observations that are part of different business processes. While there are no restrictions that a particular element of the input data should participate in a single process, it is useful to spend more effort analyzing those events that are part of multiple processes. That helps not only to identify potential bottlenecks in the operations but also to perform additional tests on what steps could be optimized or bundled together.

![Figure 1. Business process discovery in support for TRL](image)

2.1. Data collection and pre-processing

Data collection and preprocessing is the first step that needs to be considered. It is particularly important as cleaning up the inputs can reduce the dimensions of the data to be analyzed. Preprocessing is also essential for making sure that different characteristics of analyzed events are properly encoded and prepared for further analysis.
2.2. Complexity assessment and visualization

This step contributes to achieving two major goals. The first one is to provide an estimate on how complicated different processes are, as this allows to focus on those that are particularly tough to examine. It should be noted that complexity of a process is not the same as its business importance. Thus, the second goal of this step is to make sure that only relevant data is passed for further analysis. Considering possibilities for fully automated assessment, this part is particularly prone to errors and may require regular support and assistance from experts.

2.3. Mapping and map reduction

Mapping and map reduction of inputs plays important role for complex systems, where summary of similar steps can simplify further processing. This step contributes to the final results but building two intermediate output data sets – a map between events and logical processes and a set of combined (summarized) steps that can be used to simplify data handling.

2.4. TRL metrics selection and assessment

At this point typical TRL metrics like those suggested by Sauser et all [13] and Yaseri [14] can be extended with parameters indicating process complexity (length, cycles, inter-dependencies etc.). There are multiple possible metrics that can be used to estimate complexity of the business process, once it has been presented in a proper notation. While they are all relevant to the internals of the process, from management point of view the leading role should be attributed to one single metric – how much does this process contribute to reaching specified goals (for example to generating higher profit or serving more customers).

From an economic point of view, a particularly important characteristic of different processes is their throughput – time required to complete a specific process. When combined with step 2.5, changes in this parameter can be used to estimate the effects from particular management decisions as well as to account for the time needed to move to the next readiness level. To be able to measure economic impact we use the following complexity metric, applied to each step/node in the process:

\[ C_i = \sqrt{n_i \cdot x_i}, \]  

(1)

where \( n_i \) is the number of inputs required to start this point and \( x_i \) is the number of outputs from this particular step, that are on their own turn used by next steps. There are other ways to measure the impact, including adapted metrics of cyclomatic complexity used in software analysis, although we prefer to keep calculations very simple and easy to understand. For the complete process we estimate the impact as weighted average of complexity metrics, using available free capacity (e.g. possible increase in intensity or workload on each node that would not require additional investment or changes in technology):

\[ C = \frac{\sum w_i c_i}{\sum w_i}, \]  

(2)

where \( w_i \) is the respective weight, calculated as the time throughput of the node relative to the total time required to complete the process, multiplied by the one, minus the percentage of available spare capacity:

\[ w_i = \frac{t_i}{\sum t_i} (1 - f c_{\%}), \]  

(3)

Weight calculation puts emphasis on the fact that operations being able to easily cope with additional load are better prepared for changes and could be used to handle future changes and challenges. Once calculated weights could be further normalized so that then sum up to 1 in order to simplify the calculations. We prefer not to do this, as there is additional benefit for managers to see directly how weight values are influenced by individual factors.
2.5. Monitoring and re-assessment
Monitoring and re-assessment is essential to make sure that management decisions are continuously supported as business conditions change [15]. When all described steps are repeated that also gives possibility to use them for simulation and estimation of future development. Therefore, iterations are inherent part of the suggested model.

3. Application and results
We use publicly available data on EU Common Agricultural Policy, which is part of BPI Challenge 2018 [15]. Only 253K events have been analyzed in order to reduce the amount of processing time and only cases with refusal have been analyzed. This would correspond to an attempt to assess TRL for automatic check, validation and refusal of applications. We have analyzed data with R and visualization and case handling has been performed with bupaR package [16].

Figure 2. Process map and activity trace of the refusal cases

Activity trace and process map of the refusals shown on Figure 2 indicate that mapping and reduction can significantly reduce the amount of data being processed and can also help focus management attention to particularly important areas instead of just presenting specific activities. With mapping of the activities, instead of 30 different entries their number can be reduced to 8.
Differences in mean throughput time as shown on Figure 3 show how process features can be used in order to assess how technological changes will affect different steps. As data shows the refusals tend to have much more diverse timing requirements which is expected as there may be quite different reasons for rejecting a request as in this particular data set. Referring to TRL levels that would mean that much more detailed analysis would be needed when analyzing impact of management decisions on steps leading to refusal. Therefore, it would be more accurate to separate these steps and study their readiness separately.

When there is no huge difference between separate processes or cases, then economic impact metrics can support focusing on those steps and features that have highest contribution for achieving the goals set. Thus, if one step has 4 inputs required, single output and only 5% spare capacity its metric would be twice as large, as similar step having a single input and a single output.

4. Conclusion

Managers can take advantage of technological readiness level assessments in order to focus their attention on critical issues and opportunities in their organization. Despite being a useful tool that can combine diverse technical information into easy to understand and communicate way, TRL success depends on correct understanding of business processes and how different technologies fit in. We suggest an iterative procedure that can utilize process mining algorithms and give an overview of the actual business processes. In contrast to theoretically developed steps, event logs can shed light on the real time necessary to perform a specific action and about the actual relations between parts of the organization.

Using open data set we applied suggested steps in order to demonstrate how preprocessing and complexity checks can simplify further data processing and identify what are the most important steps in the underlying business activities. Process discovery and throughput analysis are important for correctly studying economic impact on different management decisions and importance of discovered processes and steps. Combination of process mining can therefore provide for better TRL assessment and decisions that are aligned with organization objectives.

This report is funded from the National Science Program "Healthy Foods for a Strong Bioeconomy and Quality of Life" of the Ministry of Education and Science, approved by decision of the Council of Ministers No577 / 17.08.2018, contract No 68 / NSP under Work Package 4.3 "New generation of value-added chains in bio-economy".
References

[1] J. C. Mankins, "Technology readiness levels," NASA, April 6 1995.

[2] HQ Office of the Chief Engineer/Steven Hirshorn and HQ Office of the Chief Technologist/Sharon Jefferies, "Final Report of the NASA Technology Readiness Assessment (TRA) Study Team," NASA Technology Readiness Assessment (TRA) Study Team, 2016.

[3] J. R. Lavoie and T. U. Daim, "Technology Readiness Levels Improving R&D Management: A Grounded Theory Analysis.," Portland International Conference on Management of Engineering and Technology (PICMET), pp. 1-9, 2017.

[4] C. A. Bates and C. Clausen, "Engineering Readiness: How the TRL Figure of Merit Coordinates Technology Development," Engineering studies, vol. Feb 19, pp. 1-30, 2020.

[5] S. Lokuge, D. Sedarah, V. Grover and X. Dongming, "Organizational readiness for digital innovation: Development and empirical calibration of a construct," Information & Management, vol. 56, no. 3, pp. 445-461, 2019.

[6] J. Straub, "In search of technology readiness level (TRL) 10," Aerospace Science and Technology, vol. 46, pp. 312-320, 2015.

[7] J. Weber, "WEC Technology Readiness and Performance Matrix–finding the best research technology development trajectory.," in Proceedings of the 4th International Conference on Ocean Energy, Dublin, Ireland, 2012.

[8] A. Neda, A. Albadvi and Z. Ferdowski, "Assessing readiness for business process reengineering," Business Process Management Journal, vol. 14, no. 4, pp. 497-511, 2008.

[9] M. Sanjay, A. Choudhury and K. Ganesh, "Framework for supporting/business process reengineering-based business models.," International Journal of Business Innovation and Research, vol. 13, no. 4, pp. 451-474, 2017.

[10] A. Adriano, R. Conforti, M. Dumas, M. La Rosa and G. Bruno, "Automated discovery of structured process models: Discover structured vs. discover and structure.," International Conference on Conceptual Modeling, pp. 313-329, 2016.

[11] E. Marc, A. Koschmider and A. Oberweis, "Measuring similarity between semantic business process models.," Proceedings of the fourth Asia-Pacific conference on Conceptual modelling-Volume, vol. 67, pp. 71-80, 2007.

[12] V. Kazashka, M. Ruseva and P. Stoyanova, "Mapping and ranking of cultural and creative industries in the city of Plovdiv," in CBU INTERNATIONAL CONFERENCE ON INNOVATIONS IN SCIENCE AND EDUCATION, Prague, 2017.

[13] S. Kabaiyanov and V. Markovska, "Making a Difference: Accounting for the Impact of Management Decisions in Environmental Management," Scientific Annals of Economics and Business, vol. 66, no. 2, pp. 131-139., 2019.

[14] B. Sauser, J. Ramirez-Marquez, D. Henry, D. Dimarzio and J. Rosen, "Methods for Estimating System Readiness Levels. The School of Systems and Enterprises White Paper.," Stevens Institute of Technology, Hoboken NJ, 2007.

[15] S. Yasser, "Subsea system readiness level assessment," International Journal of Underwater Technology, vol. 31, pp. 77-92, 2013.

[16] T. Mihova and V. Nikolova-Alexieva, "Approaches and challenges in the application of high technology in the industry," International scientific journal "Science. Business. Society", vol. IV, no. 3, pp. 105-110, 2019.

[17] B. F. van Dongen, "BPI Challenge 2018," 4TU.ResearchData, 2018, 2018.

[18] G. Janssenswillen, B. Depaire, M. Swennen, M. Jans and K. Vanhoof, "bupaR: Enabling reproducible business process analysis," Knowledge-Based Systems, vol. 163, pp. 927-930, 2019.