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A novel model for assessing the degree of intelligent manufacturing readiness in the process industry: process-industry intelligent manufacturing readiness index (PIMRI)

Key words: Process industry; Industry 4.0; Readiness model; Intelligent manufacturing; Readiness index

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Background

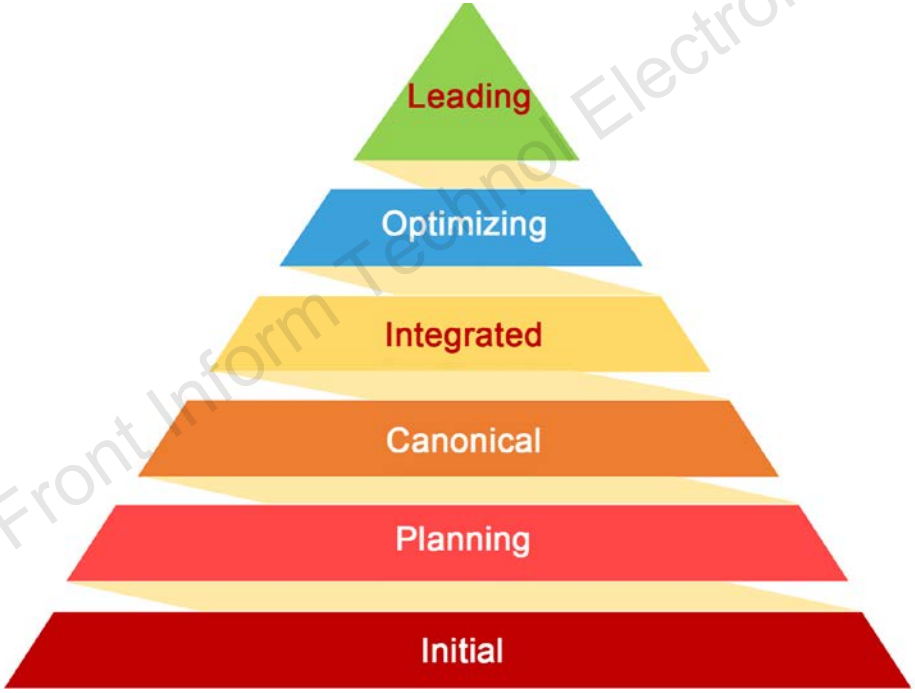
- The implementation of Industry 4.0 has become a new tendency, and it brings both opportunities and challenges to worldwide manufacturing companies.
- Many manufacturing companies are attempting to find advanced technologies to launch intelligent manufacturing transformation.
- However, Industry 4.0 covers a very wide range, which brings many difficulties to industrial companies during intelligent manufacturing transformation, such as where/how to start and what is the direction.
- A well-designed readiness/maturity model could guide companies in recognizing their current stage and short slabs when carrying out intelligent manufacturing transformation.
- Therefore, it is important to design a new readiness model to help manufacturing companies evaluate their level of intelligent manufacturing.

Motivation

- Many readiness/maturity models have been proposed, but few publications have reported their real applications in intelligent manufacturing evaluation for industrial companies.
- In fact, there are some gaps between the theoretical model and real-world application. We conclude three main reasons that lead to this problem:
  - ✓ Most of the readiness/maturity models cover a wide range of different types of companies; in other words, the models lack specificity.
  - ✓ Many readiness/maturity models can only be used by designers or experts, leading to poor usability.
  - ✓ The subjective thinking of the evaluator would disturb the accuracy of the evaluation result. Thus, it usually cannot reasonably reflect the requirements of intelligent manufacturing.
- This work aims to measure the degree of process-industry intelligent manufacturing readiness in relation to the implementation of Industry 4.0.

Method: The level of readiness model

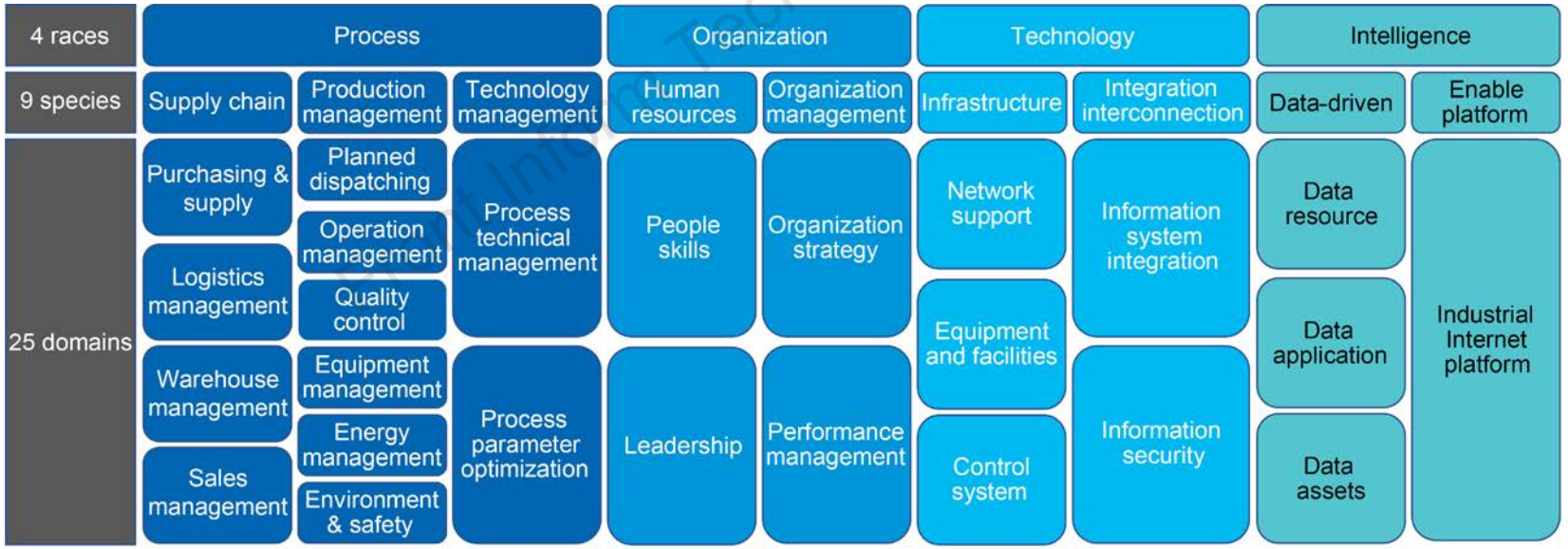
- The level distribution is the first part for the proposed model, whose level definitions are similar to those in GB/T 39116-2020, including six levels.



Six levels of the process-industry intelligent manufacturing readiness model

Method: The new proposed readiness model

- In this study, the structure and evaluated dimensions of the newly proposed model are designed using a literature review and conceptual method.
- The process-industry intelligent manufacturing readiness model comprises 4 races, 9 species, and 25 domains.
- Furthermore, the 25 domains are divided into 249 characteristic items to evaluate the manufacturing readiness in detail.



The pocess-industry intelligent manufacturing readiness model

Method: Assessment approach-PIMRI

- The process of readiness index evaluation in a company follows a five-step procedure.
- A questionnaire is also designed based on the proposed model to help process-industry companies easily carry out self-diagnosis.

Five-step procedure to assess intelligent manufacturing readiness

- The readiness indexes were calculated by the following equations:

Characteristic item readiness index: $R_c = \frac{\sum_{i=1}^{n_q} S_{q,i}}{n_q}$

Domain readiness index: $R_{d,l} = \frac{\sum_{i=1}^{n_c} R_{c,i}}{n_c}$

Species readiness index: $R_{s,l} = \sum_{i=1}^{n_d} R_{d,l,i} \cdot g_{d,l,i}$

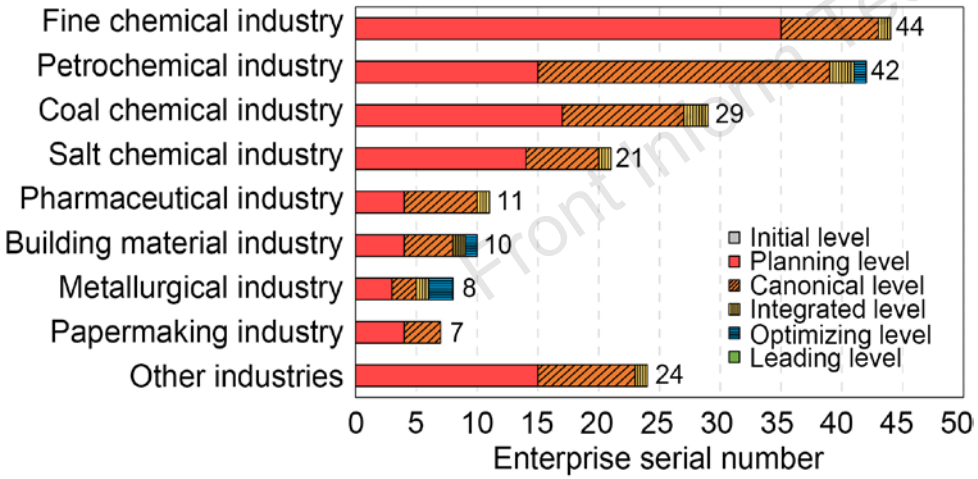
Race readiness index: $R_{r,l} = \sum_{i=1}^{n_s} R_{s,l,i} \cdot g_{s,l,i}$

Overall company readiness index: $R_{o,l} = \sum_{i=1}^{4} R_{r,l,i} \cdot g_{r,l,i}$

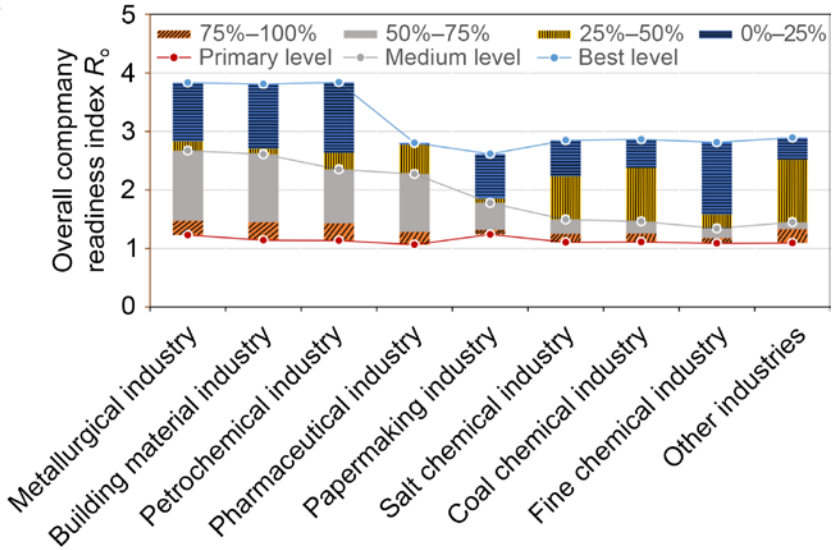
Final readiness index: $R_x = (l' - 1) + R_{x,l'}$

Major results: A case of 196 companies

- A total of 196 Chinese process-industry companies have been selected and evaluated using this newly proposed model.
- There are quite large quantities of companies that are placed in the early stage of intelligent manufacturing.
- Metallurgical industry, building material industry, and petrochemical industry have better development compared with the other six industries.



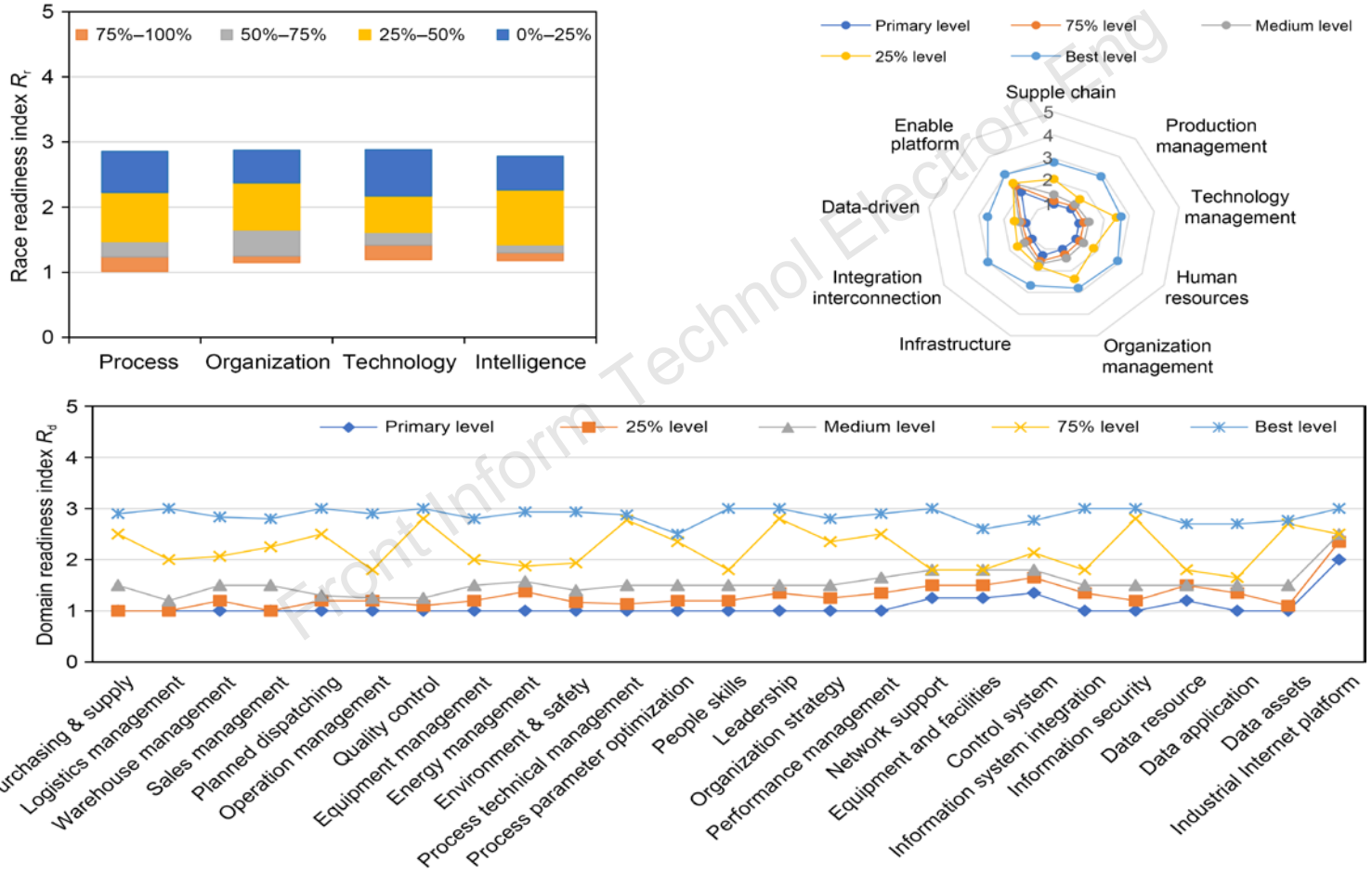
Industry distribution of the 196 Chinese process-industry companies



Readiness index distribution of the 196 Chinese process-industry companies in nine specific industries

Major results: A particular industry evaluation

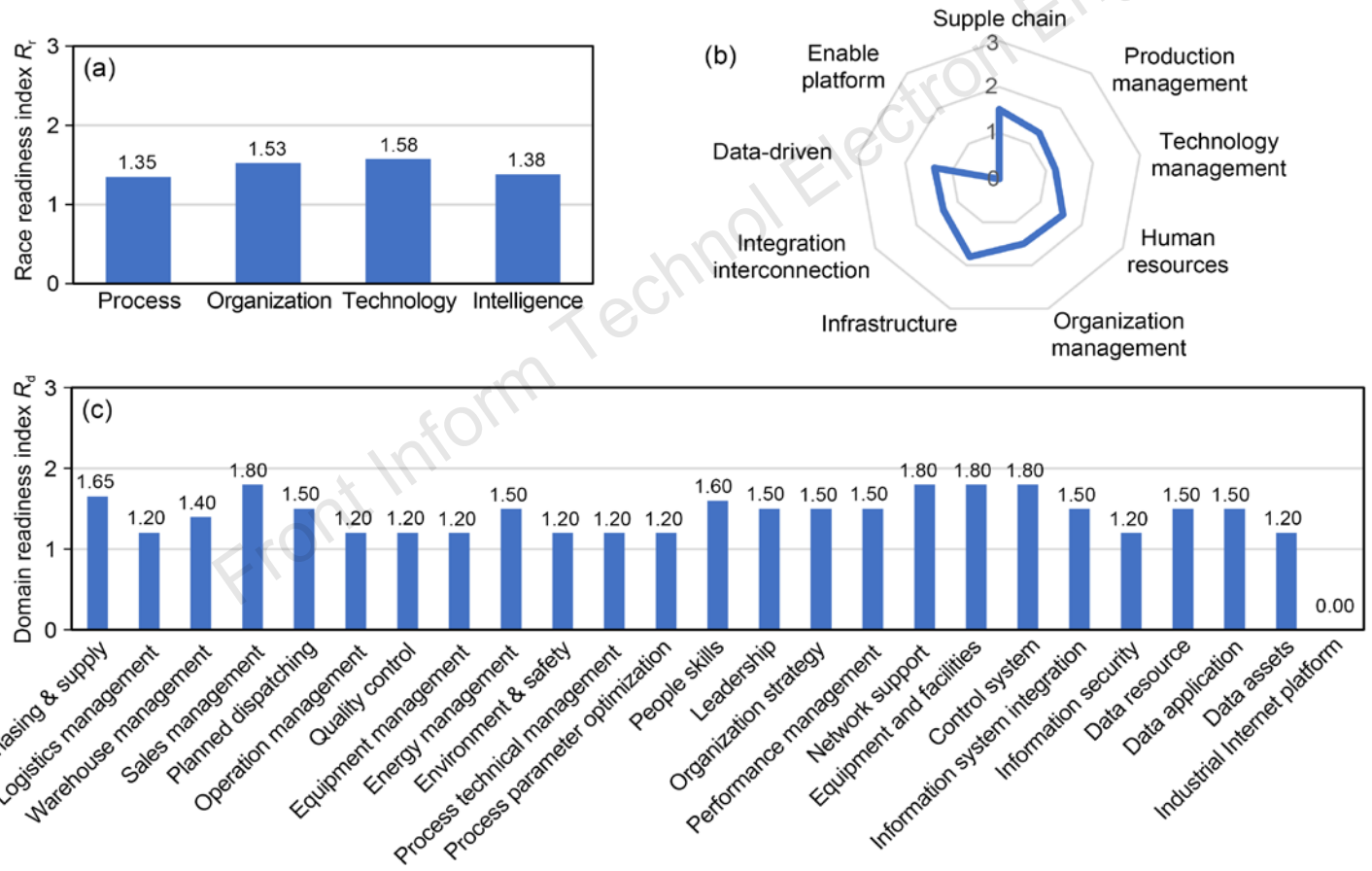
- The fine chemical industry is selected as an example to show how to use the PIMRI in a particular industry.



Readiness index distribution of the 44 companies in the fine chemical industry

Major results: Company evaluation

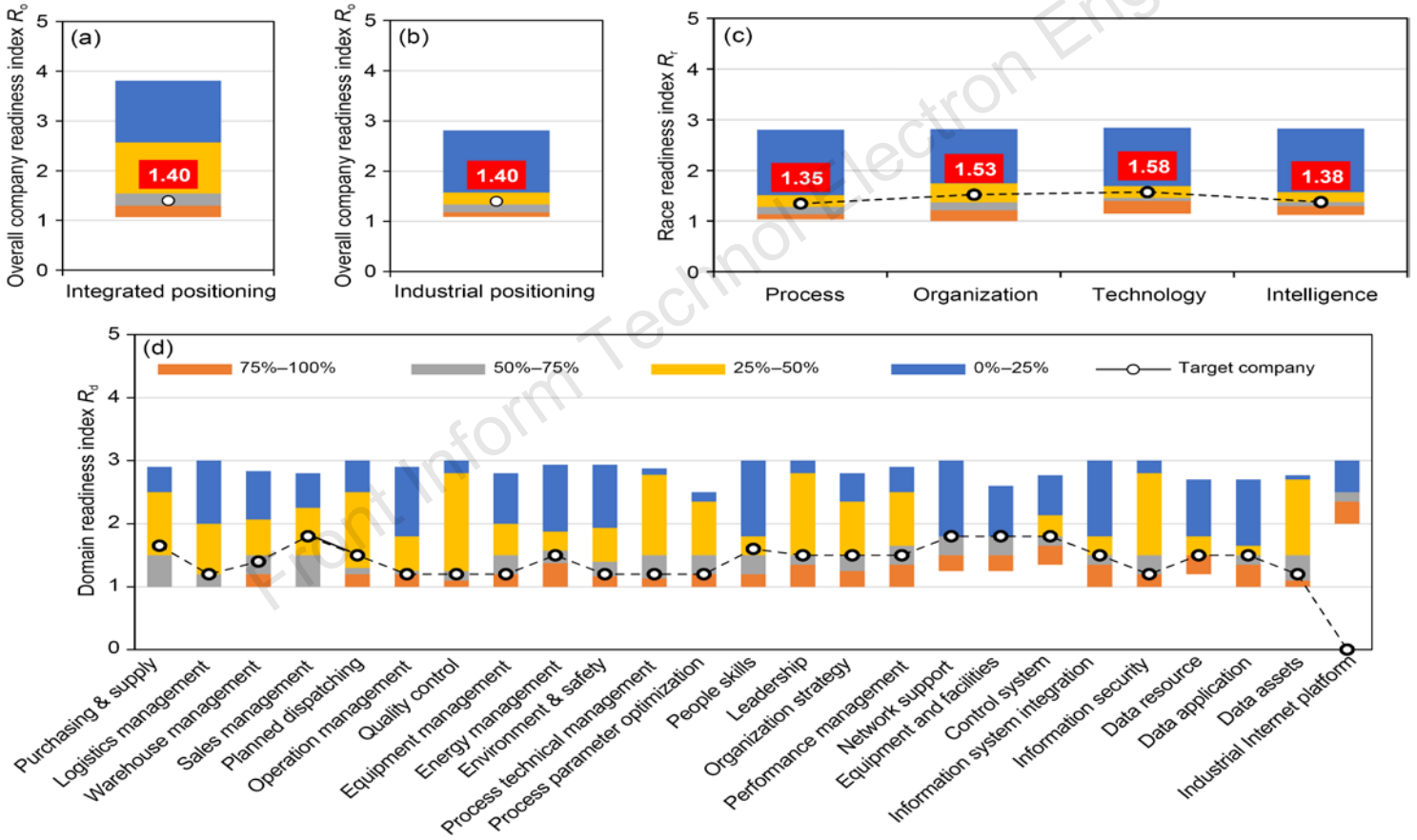
- Another fine chemical company out of the 196 evaluated companies was selected to show how a company uses the PIMRI to analyze intelligent manufacturing capabilities by self-diagnosis.



The readiness index of the target company

Major results: Company evaluation

- The position of target company intelligent manufacturing readiness in the 196 process-industry companies and 44 fine chemical industry companies.



Readiness index of the target company: (a) integrated positioning of R_o in 196 companies; industrial positioning of R_o (b), R_r (c), and R_d (d) in 44 fine chemical industry companies

Conclusions

- This work proposes a novel model that focuses on the process industry to measure the intelligent manufacturing readiness for companies, and the newly proposed model is the first model that has been created specifically for the process industry.
- The disscusion of a real-world case for 196 process-industry companies has verified the usability of this newly proposed model.
- The PIMRI could not only give guidelines for the target company but also provide industry information or a tool to evaluate the readiness degree of intelligent manufacturing for the government, solution vendors, or some third-party consulting companies.
- Finally, we hope that the PIMRI will have a positive effect on the intelligent manufacturing transformation for process-industry companies.

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