Comparison of Industry 4.0 Requirements between Central-European and South-East-Asian Enterprises

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Abstract

Industry 4.0 provides a variety of concepts and technologies to create competitive advantages for industrial enterprises and small- and medium-sized enterprises as well. Thereby, the successful implementation of new concepts and technologies in the areas of interconnectivity, digitalization, and automatization is dependent on a multitude of complex requirements. Based on expert workshops and an international survey, the authors developed and preliminarily validated a set of Logistics 4.0-related requirements for the effective implementation of Industry 4.0 in manufacturing enterprises. In this paper, the authors compare and discuss significant differences regarding the requirements of Central-European and South-East-Asian enterprises. Moreover, based on the empirical results, future directions for both enterprises and research are outlined and discussed in the course of this study.

Keywords
Industry 4.0, Logistics 4.0, Small- and medium-sized Enterprises

1. Introduction

Industry 4.0 concepts and technologies, which mainly can be classified to the areas of enhanced interconnectivity, digitalization and autonomization (Zsifkovits and Woschank 2019; Woschank and Zsifkovits, 2021), provide a multitude of opportunities for both, industrial enterprises and for small- and medium-sized companies to enhance their long-term competitiveness in the global market (Modrak et al. 2014). However, most of the recent studies do not consider the requirements which are needed for the successful implementation of Industry 4.0 concepts and technologies in industrial enterprises (Glass et al. 2018; Luthra and Mangla 2018; Woschank et al. 2020). Also, to the best of our knowledge, a systematic comparison of Industry 4.0 barriers and requirements in an international setting is still missing in the current literature.

This study focuses on the systematic evaluation of Logistics 4.0-related requirements on an international level in Central-European (Austria and South Tyrol) and South-East-Asian (Northern

Thailand) enterprises. Austria aims to become an innovation leader within the European Union. However, recent studies show that Austria lags behind the leading European countries regarding the implementation of ICT and the usage of digital technologies, especially in the industrial sector (Hölz et al. 2019). Some of the main reasons for the slow adaptation of digital technologies are 1) low managerial quality, 2) a lack of ICT skills, and 3) a poor worker/job alignment (Andrews et al. 2018). Thailand, on the other hand, as an emerging economy within South-Asia, is regarded as the world´s fastest-growing internet region, while ASEAN's digital economy has also been predicted to reach a value of USD 2 trillion by 2025 and, in 2018, it was estimated that approximately 17% of Thailand's GPD was derived from the digital economy (Thailand Board of Investment 2019). However, Thailand is lagging in terms of digital economy legislation, which must be updated and, therefore, further developed soon (Bukht and Heeks 2018).

Based on a theoretical framework of barrierless and enablers of Industry 4.0 initiatives and subsequent expert workshops, the authors developed a set of Logistics 4.0-related requirements. These items were further validated by an international survey. In this paper, the authors use the survey data to evaluate significant differences in the Logistics 4.0-related requirements between Central-European (Austria and South Tyrol) and South-East-Asian (Northern Thailand) enterprises.

2. Research Methodology

To exploratively investigate potential requirements regarding the implementation of Industry 4.0 the research team conducted five expert workshops and collected a total of 548 statements in Central-Europe, North-East-Asia, and the USA. Out of the 548 statements, the research team isolated 203 Logistics 4.0-related statements of further research. The 203 Logistics 4.0-related requirements subsequently were pre-clustered to the following areas: 1) lean and agility; 2) real-time status; 3) digitization, connectivity and network; 4) tracking, production planning and control and warehouse management systems; 5) culture, people, and implementation; 6) security and safety; 7) ease of use; 8) transportation; and 9) automation. Moreover, based on the Logistics 4.0-related clusters and statements, the research team defined items for further research (Dallasega et al. 2019; Dallasega et al. 2020):

1. The assurance of data security throughout the supply chain.
2. The availability of real-time order information regarding the status of production and shipping throughout the supply chain.
3. The transparency of inventory levels and storage locations throughout the supply chain.
4. The on-demand (Just-in-Time) production and delivery of products to the customers.
5. The identification and avoidance of material flow breaks throughout the supply chain.
6. Advanced planning and control systems for rapid demand changes.
7. Training employees on state-of-the-art software and data analysis tools.
8. The digital connection of customers and suppliers for an improved collaboration throughout the supply chain.
9. The alignment of ERP/database systems throughout the supply chain.
10. The digital tracking of products throughout the supply chain.
11. The usage of decision support systems for planning and controlling of logistics (e.g. for supplier selection decisions).

12. Work instructions for collaboration throughout the supply chain by using information and communication technology.
13. The usage of automated ordering systems.
14. The self-control of warehousing processes (autonomous processes).
15. The self-control of material flow processes (autonomous processes).
16. The limitation of data accessibility to different stakeholders in the supply chain.

In the next step, the authors conducted an international survey to validate the importance of the items, where the participants had to rank the 16 previously defined statements of Logistics 4.0-related requirements by using a Likert scale from 1=not at all important to 6=very important.

3. Comparison of Survey Results

Within the subsequent survey process, the authors contacted a total of 9,140 participants by using an online-based questionnaire and a hybrid combination of random and theoretical sampling in Central-Europe (Austria and South Tyrol) and South-East-Asia (Northern Thailand) leading to a final sample of 138 fully completed responses equating to a response rate of 1.5%. Moreover, a non-response bias test, as suggested by Armstrong and Overton (1997), did not result in significant differences between the earlier and later respondents. An additional independent t-test revealed no significant differences in the Central-European sample, between the responses from Austria and South-Tyrol. Consequently, the results of the statistical procedures will be described in the next sub-chapters of this paper.

3.1 Descriptive Analysis

Figure 1 displays the distribution of company size/number of employees in the total sample.

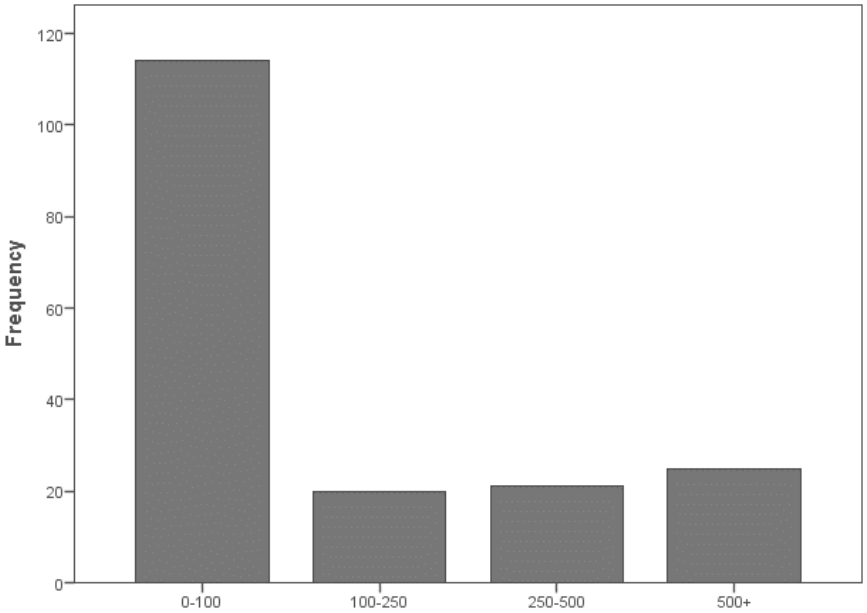

Figure 1. Distribution of company size/number of employees (total sample)

Considering the company size/number of employees, 63.3% of respondents are from enterprises with 0-100 employees, 11.1% from enterprises with 100-250 employees, and 11.7% from enterprises with 250-500 employees. The remaining 13.7% are from enterprises with more than 500 employees. Moreover, the country-specific analysis regarding the variable 'company size/number of employees' is displayed in Table 1.

Table 1. Distribution of company size/number of employees
(total sample, Central-Europe (CE), South-East-Asia (SEA))

Company size/ number of employees	Total	Total (%)	CE	CE (%)	SEA	SEA (%)
0-100	114	63.3%	26	36.1%	88	81.5%
100-250	20	11.1%	18	25.0%	2	1.9%
250-500	21	11.7%	14	19.4%	7	6.5%
500+	25	13.9%	14	19.4%	11	10.2%
Missing values	0	0.0%	0	0.0%	0	0.0%
	180	100.0%	72	100.0%	108	100.0%

In both countries, SMEs are considered the backbone of the local economy. In Austria, SMEs represent 99% (Statistik Austria 2020) and in Thailand 99.78% of the total number of enterprises (Maranate 2018). In the sample, the maturity of respondents can be assigned to the category of SMEs. However, most of the companies from the Thailand sample have fewer than 100 employees and most of them were micro-enterprises with fewer than 10 employees.

Figure 2 displays the distribution of job profiles in the total sample.

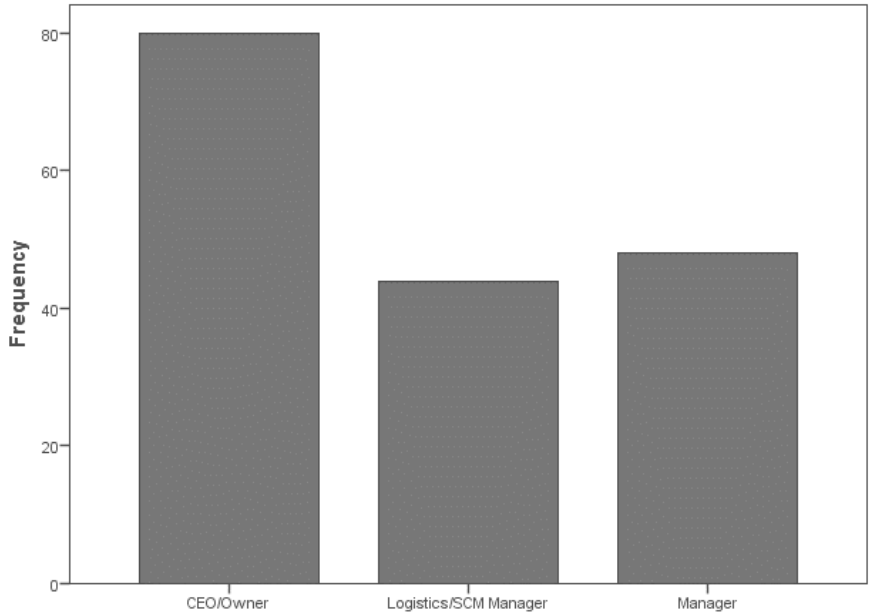

Figure 2. Distribution of job profiles (total sample)

From the perspective of production- and/or logistics-related job profiles, 44.4% of the respondents are CEO/owners of the companies, 24.4% are Logistics/SCM managers, and 27.6% work in a

production- and/or logistics-related management position; 4.4% of the participants did not provide any information concerning their job profile. The country-specific analysis regarding the variable 'job profile' is displayed in Table 2.

Table 2. Distribution of job profiles
(total sample, Central-Europe (CE), South-East-Asia (SEA))

Job Profile	Total	Total (%)	CE	CE (%)	SEA	SEA (%)
CEO/Owner	80	44.4%	20	27.8%	60	55.6%
Logistics/SCM Manager	44	24.4%	32	44.4%	12	11.1%
Manager	48	26.7%	20	27.8%	28	25.9%
Missing values	8	4.4%	0	0.0%	8	7.4%
	180	100.0%	72	100.0%	108	100.0%

In logical consistency with the company size/number of employees, most job profiles in Central-Europe are conceptualized as a specialist function of a Logistics/SCM manager, whereas, in South-East-Asia, the CEO/owners of the companies are responsible for the production- and/or logistics-related tasks.

Figure 3 displays the distribution of industry types in the total sample.

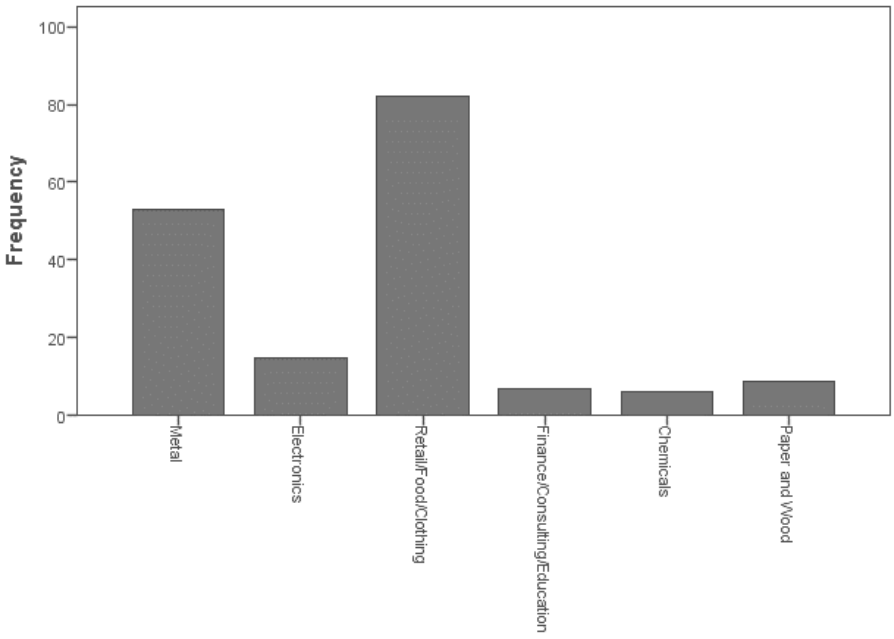

Figure 3. Distribution of industry types (total sample)

Respondents are mainly from the retail/food/clothing (45.6%) and the metal industries (29.4%) as well as from the electronics (8.3%), paper/wood (5.0%), finance/consulting/education (3.9%), and chemicals (3.3%); 4.4% of the participants did not provide any information concerning their type of industry. The country-specific analysis showing the grouping variable 'job profile' is displayed in Table 3.

Table 3. Distribution of industry type
(total sample, Central-Europe (CE), South-East-Asia (SEA))

Industry Type	Total	Total (%)	CE	CE (%)	SEA	SEA (%)
Metal	53	29.4%	39	54.2%	14	13.0%
Electronics	15	8.3%	9	12.5%	6	5.6%
Retail/Food/Clothing	82	45.6%	17	23.6%	65	60.2%
Finance/Consulting/Education	7	3.9%	1	1.4%	6	5.6%
Chemicals	6	3.3%	4	5.6%	2	1.9%
Paper and Wood	9	5.0%	2	2.8%	7	6.5%
Missing values	8	4.4%	0	0.0%	8	7.4%
	180	100.0%	72	100.0%	108	100.0%

From a country-specific point of view, most of the responders from Central-Europe (54.2%) work in the metal industry, whereas, in South-East-Asia, the maturity of enterprises can be assigned to the category retail/food/clothing.

3.2 Evaluation of Significant Differences in the Logistics 4.0-related Requirements

In this sub-chapter, the authors systematically evaluate significant differences in the Logistics-4.0-related requirements between Central-Europe and South-East-Asia. An overview of the statistical analysis is displayed in Table 4.

Table 4. Logistics 4.0-related requirements
(total sample, Central-Europe, South-East-Asia)

			Central-Europe		South-East-Asia		
No.	Item	N	Mean	Std.Dev.	Mean	Std.Dev.	p-Value
1	The assurance of data security throughout the supply chain.	180	4.22	0.86	3.88	0.86	0.01***
2	The availability of real-time order information regarding the status of production and shipping throughout the supply chain.	180	4.10	0.89	4.29	0.81	0.14
3	The transparency of inventory levels and storage locations throughout the supply chain.	180	4.39	0.80	4.05	0.89	0.01***
4	The on-demand (Just-in-Time) production and delivery of products to the customers.	180	4.10	0.92	3.95	0.87	0.29
5	The identification and avoidance of material flow breaks throughout the supply chain.	180	3.85	0.93	3.98	0.85	0.32
6	Advanced planning and control systems for rapid demand changes.	180	4.00	0.84	3.81	0.82	0.14
7	Training employees on state-of-the-art software and data analysis tools.	180	3.83	0.95	4.05	0.88	0.12
8	The digital connection of customers and suppliers for an improved collaboration throughout the supply chain.	180	3.76	0.93	3.97	0.86	0.13

9	The alignment of ERP/database systems throughout the supply chain.	180	4.17	0.95	4.16	0.87	0.95
10	The digital tracking of products throughout the supply chain.	180	3.38	0.86	3.91	0.85	0.00***
11	The usage of decision support systems for planning and controlling of logistics (e.g. for supplier selection decisions).	180	4.01	0.86	3.83	0.84	0.16
12	Work instructions for collaboration throughout the supply chain by using information and communication technology.	180	3.86	0.88	3.98	0.84	0.36
13	The usage of automated ordering systems.	180	4.29	0.81	4.18	0.87	0.37
14	The self-control of warehousing processes (autonomous processes).	180	3.72	0.94	3.85	0.87	0.34
15	The self-control of material flow processes (autonomous processes).	180	3.64	0.98	3.83	0.86	0.17
16	The limitation of data accessibility to different stakeholders in the supply chain.	180	3.68	0.90	3.89	0.88	0.12

In Central-Europe, the most important requirements are based on information- and automatization-related success factors; namely:

- The transparency of inventory levels and storage locations throughout the supply chain (mean: 4.39).
- The usage of automated ordering systems (mean: 4.29).
- The assurance of data security throughout the supply chain (mean: 4.22).
- The alignment of ERP/database systems throughout the supply chain (mean: 4.17).
- The availability of real-time order information regarding the status of production and shipping throughout the supply chain (mean: 4.10).

In South-East-Asia, the most important requirements are mainly based on information- and training-related success factors; in detail:

- The availability of real-time order information regarding the status of production and shipping throughout the supply chain (mean: 4.29).
- The usage of automated ordering systems (mean: 4.18).
- The alignment of ERP/database systems throughout the supply chain (mean: 4.16).
- The transparency of inventory levels and storage locations throughout the supply chain (mean: 4.05).
- Training employees on state-of-the-art software and data analysis tools (mean: 4.05).

By using an independent t-Test, the authors evaluated significant differences in the 16 isolated Logistics 4.0-related requirements. Most of the items did not show any statistically significant differences, while some highly significant differences could be noticed in the following items:

- Item 1: The assurance of data security throughout the supply chain (mean Central-Europe: 4.22; mean South-East-Asia: 3.88).
- Item 3: The transparency of inventory levels and storage locations throughout the supply chain (mean Central-Europe: 4.39; mean South-East-Asia: 4.05).

- Item 10: The digital tracking of products throughout the supply chain (mean Central-Europe: 3.38; mean South-East-Asia: 3.91).

4. Conclusion

In this paper, based on 548 statements from explorative expert workshops, the authors developed a set of 16 Logistics 4.0-related requirements for the implementation of Industry 4.0 in manufacturing enterprises. Subsequently, an international survey was used to evaluate potential differences in the Logistics 4.0-related requirements between Central-European and South-East-Asian enterprises.

In the Central-European sample, the most important requirements are mainly based on information- and automatization-related requirements, whereas, in South-East-Asia, information- and training-related requirements were listed as the most important ones. Surprisingly, an independent t-test did not reveal significant differences in most of the Logistics 4.0-related requirements between the Central-European and the South-East-Asian sample, meaning that the stepwise developed set of Logistics 4.0-related requirements could be considered as transnational success factors regarding the implementation of Industry 4.0 concepts and technologies.

In this context, future research should extend this evaluation by including other countries in the sample and focus on the evaluation of cause-effect relationships by investigating the impact of the Logistics 4.0-related requirements on various logistics-related performance measures, e.g., cost-, time-, quality-, and flexibility-orientated variables.

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