Uncertain Supply Chain Management 11 (2023) 1783–1788

Contents lists available at GrowingScience

Uncertain Supply Chain Management

homepage: www.GrowingScience.com/uscm

The influence of the human-machine interface on operational performance through supply chain agility

Zeplin Jiwa Husada Tarigan[a*], Hotlan Siagian[a], Yonathan Palumian[a] and I Nyoman Sutapa[b]

[a]*School of Business and Management, Petra Christian University, Indonesia*
[b]*Department of Industrial Engineering, Petra Christian University, Indonesia*

A B S T R A C T

Article history:
Received April 18, 2023
Received in revised format May 29, 2023
Accepted June 18 2023
Available online
June 18 2023
Keywords:
Human-machine interface
Operational performance
Supply chain agility

Manufacturing companies continue to carry out activities by maximizing the role of the human-machine interface. Its function is to provide work effectiveness and efficiency, compliance with social distancing at the working place, and maintain the production optimum utilization level of machines. The human-machine interface, semi-automatic or fully automatic, gives a significant role to operators and supervisors in company operations to monitor production results in real time. This study examines the influence of human-machine interface adoption on operational performance through supply chain agility. Questionnaires were distributed to 77 companies in East Java, and 56 questionnaires were considered valid for analysis. The data processing results show that the human-machine interface impacts the supply chain agility with a path coefficient of 0.665. The human-machine interface affects operational performance with a path coefficient of 0.334. Similarly, supply chain agility impacts operational performance with a path coefficient of 0.306. The human-machine interface affects operational performance through an agile supply chain with a path coefficient 0.203. This result implies that firm management needs to consider adopting HMI technology to improve the firm's performance and competitive advantage. This work could also contribute to the current research in operations and supply chain management.

1. Introduction

The current COVID-19 condition has resulted in the manufacturing industry, which uses labor-intensive use, experiencing a decrease in utilization. This condition puts heavy pressure on the manufacturing industry to survive. This condition also terminated the employment of as many as 1.5 million workers (Arief, 2020). One solution to this condition is that capital-intensive manufacturing companies have adopted human-machine interface (HMI) technology. Implementing HMI provides work effectiveness and efficiency while maintaining a distance between employees while working to be safer, and production utilities are well maintained (Correa-Baena et al., 2018).

The implementation of HMI makes it easy for operators to monitor production results automatically and in real time. Machine operational results can be connected to the company's computer network system and automatically perform data entry to the company's integrated system section. HMI is a technology widely used by companies and can visually view production results in digital and analog forms. The output results in digital form directly show the production results with numbers, while analog is shown on the needle scale in the machine manual. The output results from the machine do not need to be recorded by the operator. Still, the system directly reads and enters the company's database according to the engine output results (Vanderhaegen et al., 2019).

* Corresponding author
E-mail address zeplin@petra.ac.id (Z. J. H. Tarigan)

doi: 10.5267/j.uscm.2023.6.013

The human-machine interface delivers production results on time and is integrated with the company's computer system called enterprise resources planning (Suprapto et al., 2017). Furthermore, data can be accessed by all departments within the company in real-time, following access rights and rights to change data (Somon et al., 2019). Companies can use enterprise resource planning as a tool to perform HMI by upgrading software and hardware (Tarigan et al., 2019; Tarigan et al., 2021). The company's ability to implement HMI will impact supply chain integration, supply chain flexibility, and supply chain agility for the manufacturing industry (Siagian et al., 2022). The speed with which companies obtain information in the Covid pandemic era affects the smooth operation of the operating system because it makes it easier for companies to provide information to supplier partners, retailers, third-party logistics, and customers (Jabbour et al., 2020; Basana et al., 2022). The company can also build data integration with suppliers and customers to maintain a sustainable company supply chain flow from suppliers, manufacturers, and customers (Birasnav & Bienstock, 2019; Tarigan et al., 2021). Good data integration supports the speed of accessing report information in decision-making and adapting to customer demands (Zhang et al., 2019). Top management needs to pay attention to the company's internals by controlling the production process to match supplier and customer demands and improving the company's operational performance (Truong et al., 2017). The company's internal control function can be conducted by providing equipment that uses human-machine technology interface Control over production planning and processes is a form of strategic planning to improve manufacturing companies' operational performance (Tarigan & Siagian, 2021). HMI positively impacts the company's ability to improve supply chain agility in meeting material needs, real-time inventory, and production yield (Gaudreault et al., 2017).

The company's ability to build high agility in the new normal conditions of Covid 19 and quickly make changes are essential in improving company performance. The speed of making changes according to customer demands and informing suppliers of needs increases the company's reliability and operational performance (Geyi et al., 2020). This discussion shows that the HMI technology enables companies to improve operational performance and supply chain agility since HMI provides direct support in maintaining an efficient and effective production process. HMI also supports fast and real-time decision-making so that management can make immediate and real-time decisions. Therefore, company supply chain performance from suppliers to customers can serve the customer demands. Meanwhile, an agile supply chain also supports better operational performance. This study aims to obtain the impact of the human-machine interface on improving the company's operating performance through supply chain agility.

2. Literature Review

2.1. Machine-Human Interface

The production process transforms from a manual process to a semi-automatic and fully automatic process. With this change in the production process, manufacturing companies quickly make changes from previously labor-intensive to capital-intensive. The use of technology in the production process is integrated with company systems, resulting in an interface between humans and machines in controlling the production process on an ongoing basis (Sharp et al., 2018). The use of HMI can control the overall production process on the production floor and can control the characteristics of the process under very high-temperature conditions, even at very low temperatures. HMI can quickly control the production process when there is a processing discrepancy and provide data on production results in real-time (Morariu et al., 2020). HMI can also discover new materials to reduce product defects (Correa-Baena et al., 2018). HMI makes the system more automated and reduces the error rate because the system constantly learns and reduces the same mistakes, so it is necessary to adjust the role of humans and machines (Somon et al., 2019). HMI can also visualize real-time conditions on the production floor and provide warnings when there are process disruptions or production process discrepancies (Serpen & Khan, 2018). In addition, HMI can synchronize employees' abilities with the organization's interests to achieve the expected efficiency level (Vanderhaegen et al., 2019). Based on this discussion, the following hypotheses can be proposed.

H_1: *HMI affects the company's operational performance.*

2.2. Supply Chain Agility

The company's ability to build the strength of the supply chain flow by empowering all existing components from raw material procurement, product design manufacturing processes, production parts, and on-time delivery provides added value for customers so that customers are satisfied (Chan et al., 2017; Siagian et al., 2022). An agile supply chain is achieved if the company integrates internally to quickly respond to customers and eliminate activities that do not impact product-added value (Tarigan et al., 2021). The use of HMI technology supports companies in reducing traditional systems and making production systems that are semi-automatic and fully automated. This technology is urgently needed if the company changes its labor-intensive company into a capital-intensive by implementing a human-machine interface technology (Jabbour et al., 2020). Supply chain agility is reflected in the company's ability to manage human resources, use technology, and train employees to become agile in meeting market needs that are very dynamic, flexible, rapidly changing, and highly competitive (Dubey & Gunasekaran, 2015). This discussion can formulate the second hypothesis, namely,

H_2: *HMI improves supply chain agility.*

2.3. Company Operational Performance

Firm performance is the result obtained from a management activity in a company and is used by the company to be a benchmark parameter in assessing the success of company management (Suprapto et al., 2017). Company management always considers operational and financial achievements (Tarigan & Siagian, 2021). Company performance results from activities within the company during a specific period concerning predetermined standards (Basana et al., 2022). For example, the company focuses on a larger market and efficiency in sales (Zhang et al., 2019). In addition, manufacturing companies that implement manufacturing technology and build integration with partners can provide effectiveness for the company (Birasnav & Bienstock, 2019; Tarigan et al., 2021). Market share and sales growth measure firm performance in terms of marketing performance. While financial performance is measured by return on investment, growth of return on investment, profit margin, and competitiveness (Al-Shboul et al., 2017). Firm performance is also measured by the company's return on assets, revenues, and profits (Gandhi et al., 2017). Other studies defining a company's operational performance include reduced management costs, lead time, decreased order times, material damage, and delivery delays (Truong et al., 2017). Performance measurement used by considering the operational side is determined by delivery accuracy, flexibility, ability to fulfill orders, and increasing customer satisfaction (Tarigan et al., 2019). This discussion can formulate the third hypothesis, namely.

H3: *Supply chain agility impacts an operational firm's performance.*

3. Research Method

The population of this study is companies that have used interaction technology between company employees and machines (HMI) in the East Java region. The survey was conducted using a questionnaire made in a Google form and distributed through social media to manufacturing companies in East Java. The number of respondents who collected or answered the questionnaire via the Google form link to practitioners. Researchers got 77 respondents who answered the questionnaire. Still, only 56 questionnaires were valid and could be processed further. 21 of the questionnaires that were not considered because they were not answered completely were 14, and 2 questionnaires were from the service industry. In contrast, five questionnaires stated no working relationship between employees and production machines. Based on the explanation in the introduction and the literature review, the research model can be depicted in Fig. 1.

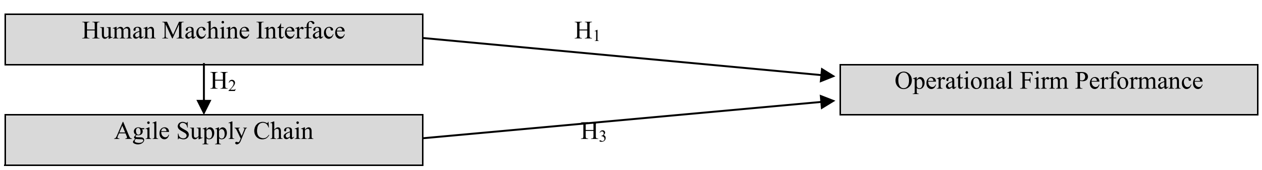

Fig. 1. Research Model and related hypothesis

Based on Fig. 1, four research hypotheses can be set as follows:

H1: *Human-machine interface has an impact on operational firm performance*.

H2: *Human-machine interface affects supply chain agility*.

H3: *Supply chain agility affects operational firm performance.*

H4: *Human-machine interface affects operational performance through supply chain agility*.

The measurements used to measure the human-machine interface are data obtained in real-time with the production process (HMI1), synchronization with company needs (HMI2), using machines that have an automated process (HMI3) (Morariu et al., 2020; Vanderhaegen et al., 2019; Correa-Baena et al., 2018). The measurement used to measure supply chain agile by adopting Tarigan et al. (2021), which consists of five measurement items Response to fulfill orders (SCA1), adjusted production capacity (SCA2), customized production planning (SCA3), production processes changed rapidly (SCA4), and the work system is adjusted (SCA5). Measurements for the company's operational performance are determined by reducing lead-time (FOP1), flexibility (FOP2), ability to fulfill orders (FOP3), and increasing customer satisfaction (FOP4) (Truong et al., 2017; Tarigan et al., 2019; Tarigan & Siagian, 2021). Processing of data collected from the distribution of questionnaires using Partial least squares. Before testing the questionnaire, the validity and reliability tests were determined as instrument model tests. The results of data processing are shown in Table 1.

Table 1. Validity and Reliability Test Result

Item Measurement	Loading Factor	Mean	Standard deviation	T-Statistic
HMI (Human Machine Interface) Reliability = 0.740				
HMI1	0.792	0.775	0.073	10.821
HMI2	0.851	0.850	0.027	31.138
HMI3	0.870	0.866	0.021	40.836
SCA (Supply Chain Agility) Reliability = 0.833				
SCA1	0.605	0.610	0.066	9.236
SCA2	0.779	0.776	0.024	32.396
SCA3	0.752	0.752	0.04	18.934
SCA4	0.739	0.734	0.055	13.53
SCA5	0.650	0.645	0.079	8.238
FOP (Firm Operational Performance) Reliability = 0.858				
FOP1	0.752	0.748	0.037	20.166
FOP2	0.659	0.653	0.060	11.054
FOP3	0.808	0.813	0.024	33.061
FOP4	0.872	0.872	0.020	43.988

Based on Table 1, the lowest loading factor value for the Human Machine Interface is 0.792 on HMI1 (data obtained in real-time with the production process) with a t-statistic of 10,821. Meanwhile, the composite reliability for HMI is 0.740. Second, in the Supply Chain Agility variable, the lowest value is found in the item SCA1 (Response to fulfill orders) of 0.605 with a t-statistic of 9.236 and composite reliability for the variable of 0.833. Third, the Firm Operational Performance variable with a value of 0.659 on the FOP2 item (flexibility) with t-statistics of 11.054 and composite reliability of 0.858. The data shows that the measurement item has been greater than 0.500, t-statistics greater than 1.96, and composite reliability has been above 0.700. It is declared to have met the validity and reliability requirements. All the above results indicate that all indicators can be declared valid and reliable. Thus, the subsequent analysis process can proceed.

4. Data Analysis

Data analysis is carried out after the validity and reliability have met the requirements, and the results of the path analysis are shown in Fig. 2 and Table 2.

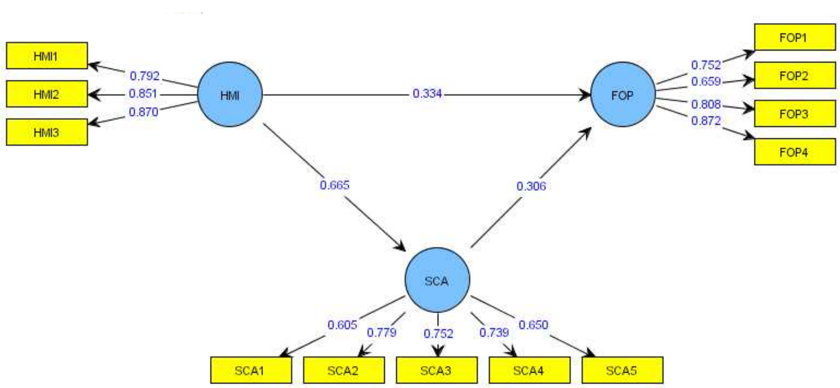

Fig. 2. Research Model and Analysis Result

Table 2
Hypotheses Testing Result

Variable	Coefficient	Standard deviation	T-Statistic
HMI → SCA	0.665	0.053	12.631
HMI → FOP	0.334	0.077	4.360
SCA → FOP	0.306	0.069	4.408

The results in Table 2 show that the first hypothesis, namely the Human Machine Interface (HMI) to Firm Operational Performance (FOP), is supported by a path coefficient of 0.335 and a t-statistic of 4.360 (greater than 2.43). The second hypothesis, the human-machine interface (HMI), affects supply chain agile (SCA) with a coefficient of 0.665 and a t-statistic of 12.631 > 2.43. The third hypothesis, supply chain agility (SCA) to Firm Operational Performance (FOP), obtained a coefficient of 0.306 and a t-statistic of 4.408 > 2.43. Thus, all the direct relationship hypotheses can be accepted. Meanwhile, for the fourth hypothesis, the Human-machine interface indirectly impacts operational performance with the mediation of supply chain agility with a coefficient of 0.665 x 0.306 = 0.203. This result supports hypothesis H4.

5. Discussion

The results of the data analysis showed that the human-machine interface (HMI) influenced firm Operational Performance (FOP) in manufacturing companies in East Java. The company's ability to synchronize workforce skills and develop machine technology in the company as needed (HM2) and use adequate automation technology (HM3) as a form of human-machine interface can impact the company's operational performance. Improvements in the company's operational performance are demonstrated by the ability to fulfill orders (FOP3) and increase customer satisfaction (FOP4). This study supports the research results, which state that the human-machine interface (HMI) impacts a firm operational performance (FOP). The company's ability to use machines that have automated processes provides an increase in firm operational performance (FOP) to fulfill orders and reduce production lead time (Sharp et al., 2018; Morariu et al., 2020; Correa-Baena et al., 2018; Vanderhaegen et al., 2019).

The results of the second hypothesis also show that the Human Machine Interface (HMI) affects supply chain agility (SCA). The company strives to produce a human-machine interface that is in accordance with the company's conditions so that it can communicate with partners and components in the supply chain. A well-coordinated supply chain can produce Adjusted production capacity (SCA2), an increase in customized production planning (SCA3), and production processes changed rapidly (SCA4). The results of this study support the results of research which state that the Human Machine Interface (HMI) affects supply chain agility (Chan et al., 2017; Tarigan et al., 2021; Jabbour et al., 2020; Dubey & Gunasekaran, 2015). Synchronizing system automation with company needs by implementing the human-machine interface (HMI) improves supply chain agile (SCA) in the company's ability to adjust production according to customer demands.

The third hypothesis is that supply chain agility (SCA) influences firm operational performance (FOP). Companies that can build supply chain agility (SCA) by demonstrating their ability in adjusted production capacity, adequate customized production planning, and rapidly changing production processes can produce increased firm operational performance (FOP). The company's supply chain agility can produce reduced lead time, flexibility of production and delivery, and the ability to fulfill orders as a form of firm operational performance. The results of this study support the results of research which state that supply chain agility influences firm operational performance (Tarigan & Siagian, 2021; Zhang et al., 2019; Birasnav & Bienstock, 2019; Al-Shboul et al., 2017; Gandhi et al., 2017; Truong et al., 2017; Tarigan et al., 2019). The company's ability to adjust production to the production plan can improve as part of the supply chain agility and operational performance through increased customer satisfaction and the ability to fulfill customer orders.

The results of the fourth hypothesis indicate that an agile supply chain can mediate Human-machine interfaces that affect firm operational performance. The company's ability to build a human-machine interface with an automation process tailored to the company's needs can improve the company's performance in fulfilling orders by accelerating the efforts of adjusted production capacity and production planning adjustments. This research contributes to developing the concept of improving firm performance and agile supply chain. These findings provide implications for practitioners to optimize the role of automation systems in production in generating production capacity and increasing customer satisfaction.

6. Conclusion

Adopting Human Machine Interface technology makes manual production machines into fully automatic or semi-automatic controlled production systems. This study has aimed to examine the effect of HMI on improving company performance by mediating supply chain agility. The study results provide conclusions: First, the human-machine interface affects firm operational performance in manufacturing companies in East Java. Second, the Human Machine Interface can improve Supply Chain Agile. Third, an agile supply chain can increase customer satisfaction and fulfill orders as a form of firm operational performance. Fourth, supply chain agility can mediate human-machine interfaces that impact operational firm performance. Finally, the results of this study affect company practitioners to be able to increase the role of the production process system that emphasizes system automation.

References

Al-Shboul, M. A. R., Barber, K.D., Garza-Reyes, J.A., Kumar, V., & Abdi, M.R. (2017). The effect of supply chain management practices on supply chain and manufacturing firms' performance. *Journal of Manufacturing Technology Management, 28*(5), 577-609, https://doi.org/10.1108/JMTM-11-2016-0154.

Arief, A.M. (2020). [Confide to the government, industry players: recovery in domestic demand is the key] Curhat ke pemerintah, pelaku industri: pemulihan permintaan domestik jadi kunci. Accessed on June 15, 2023, from https://ekonomi.bisnis.com/read/20200602/257/1247648/curhat-ke-pemerintah-pelaku-industri-pemulihan-permintaan-domestik-jadi-kunci

Basana, S.R., Siagian, H., Ubud, S., & Tarigan, Z.J.H. (2022). The effect of top management commitment on improving operational performance through green purchasing and green production. *Uncertain Supply Chain Management, 10*(4), 1479-1492, DOI: 10.5267/j.uscm.2022.6.008

Birasnav, M., & Bienstock, J. (2019). Supply chain integration, advanced manufacturing technology, and strategic leadership: An empirical study. *Computers & Industrial Engineering, 130*,142-157, doi.org/10.1016/j.cie.2019.01.021

Correa-Baena, J.-P., Hippalgaonkar, K., Duren, J.V., Jaffer, S., Chandrasekhar, V.R., Stevanovic, V., Wadia, C., Guha, S., & Buonassisi, T. (2018). Accelerating materials development via automation, machine learning, and high-performance computing. *Joule, 2*(8), 1410-1420, doi.org/10.1016/j.joule.2018.05.009.

Chan, A.T.L., Ngai, E.W.T., & Moon, K.K.L. (2017). The effects of strategic and manufacturing flexibilities and supply chain agility on firm performance in the fashion industry. *European Journal of Operational Research, 259*(2), 486-499, doi.org/10.1016/j.ejor.2016.11.006

Dubey, R., & Gunasekaran, A. (2015). Agile manufacturing: framework and its empirical validation. *The International Journal of Advanced Manufacturing Technology, 76*(9–12), 2147–2157.

Gandhi, A.V., Shaikh, A., & Sheorey, P.A. (2017). Impact of supply chain management practices on firm performance: Empirical evidence from a developing country. *International Journal of Retail & Distribution Management, 45*(4), 366-384, https://doi.org/10.1108/IJRDM-06-2015-0076

Gaudreault, J., Quimper, C.-G., Marier, P., Bouchard, M., Chéné, F., & Bouchard, J. (2017). Designing a generic human-machine framework for real-time supply chain planning. *Journal of Computational Design and Engineering, 4*(2), 69-85, doi.org/10.1016/j.jcde.2016.12.001

Geyi, D.G., Yusuf, Y., Menhat, M.S., Abubakar, T., & Ogbuke, N.J. (2020). Agile capabilities as necessary conditions for maximizing sustainable supply chain performance: An empirical investigation. *International Journal of Production Economics, 222*, 107501, doi.org/10.1016/j.ijpe.2019.09.022.

de Sousa Jabbour, A. B. L., Jabbour, C. J. C., Hingley, M., Vilalta-Perdomo, E. L., Ramsden, G., & Twigg, D. (2020). Sustainability of supply chains in the wake of the coronavirus (COVID-19/SARS-CoV-2) pandemic: lessons and trends. *Modern supply chain research and applications*, *2*(3), 117-122.

Morariu, C., Morariu, O., Râileanu, S., and Borangiu, T. (2020). Machine learning for predictive scheduling and resource allocation in large-scale manufacturing systems. *Computers in Industry, 120*, 103244, doi.org/10.1016/j.compind.2020.103244

Serpen, G., & Khan, R.H. (2018). Real-time Detection of Human Falls in Progress: Machine Learning Approach. *Procedia Computer Science, 140,* 238-247, doi.org/10.1016/j.procs.2018.10.324.

Sharp, M., Ronay A.K., & Hedberg Jr, T. (2018). A survey of the advancing use and development of machine learning in smart manufacturing. *Journal of Manufacturing Systems, 48* (Part C), 170-179, doi.org/10.1016/j.jmsy.2018.02.004.

Siagian, H., Ubud, S., Basana, S.R., & Tarigan, Z.J.H. (2022). The effect of amended order on firm resilience through supply chain coordination. *Uncertain Supply Chain Management, 10*(3), 1009-1022, DOI: 10.5267/j.uscm.2022.2.012

Somon, B., Campagne, A., Delorme, A., & Berberian, B. (2019). Human or not human? Performance monitoring ERPs during human agent and machine supervision. *NeuroImage, 186*, 266-277, doi.org/10.1016/j.neuroimage.2018.11.013

Suprapto, W., Tarigan, Z. J. H., & Basana, S. R. (2017, July). The influence of ERP system to the company performance seen through innovation process, information quality, and information sharing as the intervening variables. In *Proceedings of the 1st International Conference on Education and Multimedia Technology* (pp. 87-91).

Tarigan, Z. J. H., Lianto, & Basana, S. R., (2019). The impact of organizational commitment on upgrading ERP for maintaining the quality of information and the ERP performance. *IOP Conf. Series: Materials Science and Engineering, 473*, 012051, DOI:10.1088/1757-899X/473/1/012051

Tarigan, Z.J.H., Oktavio, A., Soeprapto, W., Harjanti, D. Malelak, M.I., & Basana, S.R., (2021). Key user ERP capability maintaining ERP sustainability through effective design of business process and integration data management. *International Journal of Data and Network Science, 5*(3), 283-294, DOI: 10.5267/j.ijdns.2021.6.005

Tarigan, Z.J.H., & Siagian, H. (2021). The effects of strategic planning, purchasing strategy and strategic partnership on operational performance, *Uncertain Supply Chain Management, 9*(2), 363-372, DOI: 10.5267/j.uscm.2021.2.006

Tarigan, Z.J.H., Siagian, H., & Jie, F. (2021). Impact of Internal Integration, Supply Chain Partnership, Supply Chain Agility, and Supply Chain Resilience on Sustainable Advantage. *Sustainability, 13*(10):5460. https://doi.org/10.3390/su13105460

Truong, H.Q., Sameiro, M., Fernandes, A.C., Sampaio, P., Duong, B.A.T., Duong, H.H., & Vilhenac, E. (2017). Supply chain management practices and firms' operational performance. *International Journal of Quality & Reliability Management, 34* (2), 176-193, https://doi.org/10.1108/IJQRM-05-2015-0072

Vanderhaegen, F., Wolff, M., Ibarboure, S., & Mollard, R. (2019). Heart-Computer Synchronization Interface to control human-machine symbiosis: a new human availability support for cooperative systems. *IFAC-PapersOnLine, 52*(19), 91-96, doi.org/10.1016/j.ifacol.2019.12.116

Zhang, J., Li, S., Zhang, S., & Dai, R. (2019). Manufacturer encroachment with quality decision under asymmetric demand information. *European Journal of Operational Research, 273*(1), 217-236, doi.org/10.1016/j.ejor.2018.08.002.