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■ *Research Paper*

A Managerial Early Warning System at a Smart Factory: An Intuitive Decision-making Perspective

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Early warning systems are becoming increasingly important in high-risk industries, because of their potential to detect all kinds of subtle threats and opportunities, that is, weak signals, in order to avoid strategic surprises. However, it is an under-researched area within the context of smart factories. For the purpose of the study, semi-structured group interviews were used to investigate how managers at a smart factory, a highly innovative global supplier in the automotive industry sense weak signals, perceive the role of intuition, smart systems and business model adjustments. The results of the study show that managers perceive early warning systems as highly important for timely response to development changes and that both smart systems and intuition play an essential role in detecting and responding to weak signals. Based on this study, we propose a managerial early warning system model with four stages, namely, identifying, screening, appraising and responding to weak signs, within the context of a smart factory. © 2018 John Wiley & Sons, Ltd.

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INTRODUCTION

The concept of early warning systems in management was first presented by Ansoff (1975), who proposed that managers, in a turbulent business environment, should prepare for a strategic surprise by responding to weak signals, which are early indicators of impending impactful events. The theory of weak signals (Ansoff, 1975) to anticipate surprising future events has become more prominent in academic research,

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and practitioners are increasingly more interested in the topic particularly those in high-risk industries. Nikander (2002, p. 49) defines an early warning sign as 'an observation, a signal, a message or some other item that is or can be seen as an expression, an indication, a proof, or a sign of the existence of some future or incipient positive or negative issue. It is a signal, omen, or indication of future developments'. According to Haji-Kazemi and Andersen (2013), the theory of weak signals is focused on fundamental changes in an organization's environment that traditional strategic planning cannot detect.

Managerial early warning systems can enable organizations to manage risks more effectively and prevent negative events, and for this reason, it is important that such early warning systems are effective and embrace all aspects of emergency. Managers in high-tech organizations have to be prepared for crises, and in case of emergency, skilful management of resources, skilled personnel, good communication equipment and efficient coordination of tasks are especially needed (Assilzadeh and Gao, 2010).

Warning signs of emerging risks are almost always out there (Gilad, 2003); however, while in many instances they are recognized, they are all too often simply ignored. In other words, 'surprised' organizations are mostly the consequence of managerial 'ignorance'. Managers, whose responsibility is to be proactive and react early on, are often caught by strategic surprise (Ansoff, 1975; Gilad, 2003). Gilad (2003) argues that this is due to internal convictions (fixated mindsets) that lead to wrong decisions resulting in performance failures.

The paper is structured as follows: it starts with the introduction and is followed by a theoretical background of early warning systems in management, along with intuitive decision-making, as explained by various authors. Literature review on managerial early warning system is also presented in this section. The third section of the paper presents methodology, thereafter the main study results are presented and discussed. Finally, implications for management and conclusions are presented.

THEORETICAL BACKGROUND

Managerial Early Warning System

Numerous studies have been performed on early warning system use in the field of natural disasters management, but only a few of them are from the field of strategic management. For this reason, in our study, we focus on managerial early warning systems.

Early warning systems serve as a key management tool for anticipating potential disasters or other negative events (Trzeciak and Rivers, 2003). They can be applied to any event, typically negative, that has the potential of occurring in the future. Several authors have researched such systems for early warning in the fields of natural disasters, meteorology and defence (Abon *et al*., 2012; Assilzadeh and Gao, 2010; Collins and Kapucu, 2008; Davis and Izadkhah, 2008; Xie and Lia, 2014), for the purpose of avoiding damage and casualties (Martin, 2007), mostly by conducting qualitative case studies.

Keil and Montealegre (2001), Lyons and Skitmore (2004), Hanna and Gunduz (2011), Espejo and Dominici (2017) and Leon (2018), among others, investigated early warning signals within the context of risk management, rather than in the context of forecasting instruments (Persson *et al*., 2015) or by looking at specific indexes that determine critical values that signal danger to the economy (Kaminsky *et al*., 1998).

Management is responsible for setting up strategies for long-term stability of their organizations (Rausand, 2011) and needs to be prepared for different crises. In preparing for possible crises, all preventive activities must be regularly tested to determine the vulnerability of organizations to the crisis (Combs, 2007).

Based on a literature review, we identified which critical factors of emergency, relevant for managerial early warning systems, were recently studied (Table 1).

According to Schwartz (2005), early warning systems in management are often not adequately implemented due to 'a lack of participation of potential future users in the implementation phase, a lack of joint understanding of the nature of trends, differing and unrevealed requirements

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Table 1 The literature review of critical factors of emergency

Author(s) (year of publication)	Critical factors of emergency
Ansoff (1975)	Weak signals and strategic surprise
Rainhardt (1984)	Early recognition of organizational problems
Milenković (2001)	Conflicts and operating costs
Keil and Montealegre (2001)	Early recognition of risk signs
Nikander and Eloranta (2001)	Detecting early warning signs
Lyons and Skitmore (2004)	Risk signs and risk management usage
Ritchie (2004)	Strategic approach to management
Schwarz (2005)	Early warning signs, differing and unrevealed requirements and lack of interaction among users
Liu *et al*. (2006)	Quality, costumers' involvement and group productivity issues
Villagrán de León *et al*. (2006)	Disaster risk management
Lin Moe and Pathranarakul (2006)	Financing, public project and natural disaster risk management
Kappelman *et al*. (2006)	Early recognition of warning signs in IT projects
Johnston *et al*. (2007)	Staff training for emergencies, emergency management exercises and hazard signage in tourism sector
Schoemaker and Day (2005, 2009)	Weak signals, personal and organizational biases and periphery
Sniedovich (2010)	Voodoo decision theories based on, e.g. based on utterly unrealistic assumptions
Laszlo *et al*. (2010)	Value cocreation and evolutionary systems design
Hanna and Gunduz (2011)	Experiences, design issues and management-related issues
Pennington Gray *et al*. (2011)	Resource allocation, experiences and communication procedures
Tsai and Chen (2011)	Instant response and risk assessment
Goldfarb *et al*. (2012)	Managerial behavior and decision-making issues
Xie and Liu (2014)	Experiences, rapid action, synergic response and corporate social responsibility
Sharaborova *et al*. (2015)	Early warning signs, complexity and competencies
Espejo and Dominici (2017)	Value cocreation for product development
Leon (2018)	Managerial early warning system implementation

Source: Authors' work. IT, information technology.

of trends by various interested parties, a broad misconception of the "weak signals" concept and trends, an excessively heavy reliance on alleged "hard data", a lack of interaction among users, and a "missing link" to the strategic functions in an organization'.

Therefore, early warning systems need to be implemented in a proactive manner both traditional and smart industries, using different business models (De Reuver *et al*., 2009), in order to manage risks and financial performance. Managers need to become aware of early warning signals while planning for the future and take proactive actions in terms of total quality management to prevent negative events (Haji-Kazem and Andersen, 2013; Pelantova and Šlaichova, 2017; Dinu, 2017). Nikander and Eloranta (2001) and Kappelman *et al*. (2006) also recognized the importance of early warning signs for avoidance of strategic surprises that are due to various development discontinuities. If we take into account the management shift from reactive to proactive management, early warning systems can be considered as an extension of an optimist view on complexity and adaptive systems (Woods and Branlat, 2011; Rud, 2011). The optimist presumes that an adaptive system has 'some ability to self-monitor its adaptive capacity (reflective adaptation) and anticipate/learn so that it can modulate its adaptive capacity' and pessimist 'see adaptive systems as trapped in a cycle of expansions, saturation and eventual collapse' (Woords and Branlat, 2011, p. 2). If we transfer the optimist and pessimist stance to the notion of early warning, we can conclude that early warning systems are the transmission of an optimist stance in a process of stepping back from the reactive to the proactive standpoint. One such example are

simulation-based early warning systems in automotive industry (Hotz, Hanisch and Schulze, 2006).

Intuitive Decision-making

Intuition is proposed to be fast, because of its evolutionary advantage to react quickly to stimuli, which is possibly due to the greater amount of items of information unconscious processes and long-term memory can work with (Dane and Pratt, 2007; Cowan, 2008; Llinás, 2009; Bargh and Morsella, 2008). As a result, intuition would have an advantage over conscious cognitive planning, for example, in its ability to process many chunks of information, as opposed to the few that can be temporarily stored in short-term and working memory when conscious analysis is occurring (Dane and Pratt, 2007; Cowan, 2008).

Intuition has been said to be seeing and recognizing, so it is likely to have an important role in detecting weak signals. The more learned and experienced a manager is about his or her field, the greater will be his or her ability to see and recognize weak signals among noise. Also involved in intuition is the ability to recognize patterns and links between information; in the case of a manager, this would be between a weak signal and its relevance as an opportunity or a threat to the organization they are working for (Day and Shoemaker, 2005; Dane and Pratt, 2007; Shoemaker and Day 2009). When managers are reacting to the crisis, particularly when the decision has a high degree uncertain, intuition becomes important (Patton, 2003). For them, intuition helps make more rapid and successful decisions and plays an important role for managers in high-ranking positions, especially when under time constraints and faced with critical and tough decisions (Agor, 1986; Brockmann and Anthony, 2002; Dörfler and Ackermann, 2012).

There is also considerable evidence of intuitive decision-making from natural sciences, where intuition is seen as a complex and sophisticated preconscious process (Dane and Pratt, 2007; Cowan, 2008; Bargh *et al*., 2008). Llinás (2009) calls this the prediction imperative and believes that it is controlled by what he terms 'the self', which can be able to plan based on previous experience and can work without self-awareness, that is, the unconscious mind, and proposes it is the most important evolutionary advantage our brain has given us.

METHODOLOGY

Research Design and Methods Used

A qualitative case study was designed, where the study was guided by the desire to present the research problem through the eyes of those involved, that is, the interviewees, and by doing so to give a detailed description with consideration to the context in which the problem was embedded. Qualitative research designs enable the researcher to gain an in-depth insight into a problem and are capable of providing valuable insights in the field of management (Sounders *et al*., 2007) as it allows for a thorough analysis to understand complex social phenomena under consideration (Yin, 2014). Empirically studying and analysing the managerial early warning system, which is under-researched, required a flexible research design and understanding of initially stated research questions as the starting point of the study. We studied the case of the TPV Group, a smart factory located in Slovenia, a highly innovative global supplier in the automotive industry. Smart factories are considered sustainable, according to the standards of a circular economy, and are highly engaged in automation, robotization and digitalization of their processes.

We used purposive ideographic sampling (Luthans and Davis, 1982) that included a sample size of four participants. This sample included top-level managers, who are the most knowledgeable informants in the company due to their expertise on the topic of the study. Before conducting the study, we decided to exclude managers that are not strategic decision makers but focus only to those on the highest management level.

Group interviews were conducted on site and had a strictly defined protocol, following the Yin (2014) approach. The interviews were taped using a smart phone voice recorder app and a

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desk microphone, to ensure that all the details were recorded and could later be transcribed to text. Before the interviews began, the interviewees were guaranteed anonymity. We used a group semi-structured interview method, while the interview protocol containing the following questions and subquestions:

(1) How do you interpret weak signals and strong signals?

1.1. How do you determine whether or not they are no false alarms?
1.2. How do you interpret detecting weak signals for the purpose of preventing strategic surprise?
1.3. What is the influence of weak signals on strategic planning? How would you otherwise predict the future, if not with weak and strong signals? Who in your organization is in charge of sensing and reacting to weak signals?

(2) Do you cooperate with external organizations, such as partners, customers and start-ups, and does this help you sense weak signals?
(3) What technological and non-technological processes in your organization use early warning systems?
(4) What role do you attribute to intuition, when dealing with weak signal detection?

4.1. How do you decrease uncertainty about the future, what do you believe is the relationship between early warning systems and intuition?
4.2. How important is intuition when there is no early warning system?

Primary data were analysed and summarized into a coherent story, namely, explaining the research phenomenon (Easterby-Smith *et al*., 2007). A qualitative content analysis (Krippendorff, 2013), the essence of which is searching for concepts and categories empirically, was used. The transcribed audio recordings were coded using the methods suggested by Campbell *et al*. (2013), with the help of the qualitative software analysis program Atlas.ti 7.0.

Reliability for in-depth interviews consists of three factors: stability, accuracy and reproducibility (Campbell *et al*., 2013). To assure stability, precautions were made so that when a code was used more than once, it would refer to the same phenomena each time. Finally, for reproducibility, we used the intercoder agreement method by Campbell *et al*. (2013), which recommends that to increase reliability, two or more coders are used to code the interview, in our case, we used three, so that the codes can be compared to see if similar codes were used, after which differences should be looked at and at least a 90% agreement on code use should be reached. Intercoder agreement was calculated using the formula by Campbell *et al*. (2013), and initially, its agreement was over 90%. Differences were compared and recoded, until 100% agreement was reached.

RESULTS AND DISCUSSION

At studied smart factory, TPV Group, weak signals are identified and responded to by looking for them throughout the world, as they told us that 'as a supplier of global automotive industry delivering to all continents, have a global presence and proactively search for weak signals by communicating practically daily with various stakeholders of the factory, ranging from our suppliers to customers'. Management sees the factory's global presence as an 'advantage and opportunity' rather than a threat, when concerning identification of weak signals. Established business networks or as they sometimes internally call them 'spider nets of partners in business' and non-equity strategic alliances enable them to stay on the cutting edge within their very competitive industry.

Unlike many of their domestic and international competitors that perished, due to persistence with traditional business models despite a dramatically changed industry environment, TPV Group started transforming into a smart factory early on and felt like they have a head start in the smart factory industry. Nowadays, the only constant in the industry is 'all-present and continuous change due to automation, robotization and digitalization'. Therefore, early on they were able to commence on the journey of

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transforming from a traditional factory to a smart factory by adapting their business model towards a more sustainable one. By looking at the market, they were able to recognize the weak signal that the automotive industry requires 'digitalized suppliers'.

By 2023, the most important yet ambitious goal for TPV Group is to become a fully automated and digitalized smart factory. However, they are aware of the fact that if they had started becoming a smart company only after 2020, by then weak signals would have turned into strong ones, and they would have missed their chance to take full advantage of the competitive edge being a smart factory currently gives them. Both warning signals, weak and strong, need to be detected on time, carefully considered at all levels and included in the 'on-going process of adaptation to market changes'; in other words, they believe that they have to proactively manage changes and have been therefore systematically building their managerial early warning system.

They state that strong adaptation capacity of the factory is an important competitive advantage and will continue to remain that way. In order to stay in business, they have been not only transforming business systems but also creating leaner organizational structure, and as a result, different sets of resources are required. Over a relatively short period, the organizational structure has 'shrunken by three levels from the previous eight', making the factory leaner and also more responsive. Fewer organizational levels within the factory also mean that management and knowledgeable employees, working in increasingly interdisciplinary teams of experts, have more interactions within TPV, as a group cooperate more with the outside world and have become 'antennas for early warning signals'.

Once a warning signal within the system is identified, Day and Shoemaker (2005) suggest the creation of fictional future scenarios of what weak signals might bring and which strategic surprises should be avoided (Shoemaker and Day, 2009). In this respect, management has to establish an early warning system, make it functional and take advantage of it when doing strategic planning and performing strategic decision-making. Early warning systems at any organization, especially in high-risk industries, have to be organizationally instrumental and become part of the strategic decision-making process. In other words, an 'early warning system as a smoke detector' has become an important managerial tool in smart factories helping managers to prepare on time and even more importantly to avoid any 'strategic surprise', to avoid missing the critical period for detecting important technological change or discontinuity.

Improving the efficiency of all systems, above all manufacturing, is the hallmark of any organization not only the smart ones. At studied smart factory, in one example out of many technological innovations at TPV Group, an application was first looked for on the market, but the options available were not satisfactory for them, so they decided to attempt to make it on their own. As a result, they teamed up with their partners and succeeded in creating such an application. At the time, none of their customers were forcing them to develop such an application, but according to them, there were 'certain weak signals coming from the market that we should do it' and gain advantage over the competition. This endeavour eventually led them to developing an automated transportation vehicle system, located in the factory. The vehicle is digitally controlled through a virtual grid that maps the factory. When the vehicle receives a signal, it will take automobile parts from one part of the factory to a desired location. In their words, that is how 'automation and robotization in the digital era, looks in practice'.

Shoemaker and Day (2009) propose using intelligence at local levels of an organization, creating networks of communication between partners, suppliers, customers and anyone related to the organization, thereby increasing the amount of information one has, and with this, potentially important weak signals can be found. At studied smart factory, a significant amount of resources has been invested into perfecting an innovation system based on incentives, where any of the 1200 employees can offer 'suggestions for innovation and weak signal identification'. According to management, their 'innovation system' for giving such suggestions is highly

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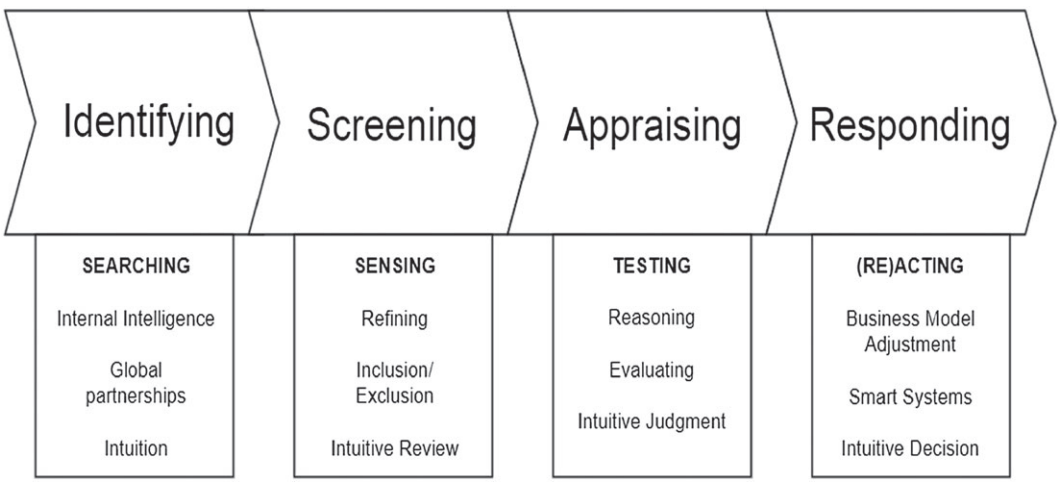
developed, and they are genuinely interested in the opinions of in-house employees. In the case of TPV, while they welcome any suggestions through their innovation system, administration and development departments are mainly in charge of identifying weak signals and of course strong signals. Sales and production departments are also strongly involved. However, according to managers, all other departments also play an important role that contribute to detecting weak signals. Overall, managers believe it would be wrong to include just certain departments and not encourage all employees to contribute with any kind of information that could benefit the factory.

At studied smart factory, management believes that next to well-functioning managerial early warning systems when dealing with an uncertain future and technological discontinuities, 'intuition is a much needed factor'. It is intuition that often guides managers or employees towards detecting a weak signal in its initial phase and find a potential solution or opportunity in the subsequent phase.

In the case of TPV, this would be the ability to predict weak signals intuitively and through rational analysis prove their significance. Once a weak signal was identified, management needs to go through 'a long process of deciding whether following up on a weak signal is worth it', because when a signal turns out to be a false alarm, there can be significant financial loss, particularly when large capital investment is required.

When working with weak signals, the future is never certain. However, although decisions based on weak signals can be called an educated guess about an uncertain future, they certainly differ from so-called voodoo decision-making theories, which also give advice about how to decide about an uncertain future (Sniedovich, 2010). As opposed to such *voodoo approaches*, which gives advice on what decision should be made, managerial early warning systems simply advise managers to be careful of dangers to their organizations that are not as obvious as when strong signals are looked at, but afterwards, it is up to management and their experience and skills to decide how to (re)act.

Despite existing mathematical models used for business purposes, long-range forecasting is still uncertain. Instead of providing mathematical formulas, we propose a cognitive-behavioral managerial early warning system, based on interviews, which helps managers prepare ahead of time, in order to avoid missing weak signals (Figure 1). These tend to be more of a psychological nature and involve many biases and heuristics. For example, managers often tend to suppress unpleasant realities or change perceptions, which can lead them to do something that



Source: Authors' work

Figure 1 Four-phase early warning system at smart factory

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is detrimental to business. Other biases can occur when individuals work in groups, which is called groupthink, and this negatively impacts decision-making through means of narrow-minded analysis, pressure to consent and bad methods of gathering information (Day and Shoemaker, 2005). This can be due to hierarchy, where top managers or other high ranking managers take control of the debate and do not welcome new thought, along with such biases as appeal to authority or making decision based on irrelevant past experience (Leon, 2018).

Shoemaker and Day (2009) also stress the importance of intuition of experienced managers, who are better able to pick up weak signals, which is also the opinion of managers at TPV. At TPV Group, managers believe that there is 'never a sure way of detecting or reacting to a weak signal'. While there is an enormous amount of weak signals worldwide, it is hard for a single manager to find them alone, so multiple managers and employees being involved are very important; however, when working alone or in groups, the managers we interviewed believe that when 'being bombarded by information it is important to have good intuition'. They see it as a 'hit or miss' situation, where intuition based on as much previous experience as possible is especially important. They stress that 'managers that do not have a well-developed intuition might get lucky eventually, but in the long run they will fail more times than succeed'. They believe they have likely missed weak signals on occasion due to the sheer volume of information flowing into the smart factory on a daily basis; however, they still believe it is crucially important to catch such weak signals early on, because it might otherwise be too late for the factory.

Finally, management at studied smart factory relies on both their early warning system as well as intuition, when identifying and responding to weak signals, in order to avoid any strategic surprise in the future. Based on numerous descriptions of their automated and digitalized smart system, it seems that there is an increasing trend towards the computational power of smart technology replacing that of human intuition. As a result, early warning system in production of automobile parts is becoming free of emotional biases and cognitive limitations of humans. However, the managers at TPV Group believe that there will still be many tasks at smart companies that will need to be run by humans, although they state that 'a higher level of education and training will become increasingly more important' in such circumstances.

CONCLUSION

Development discontinuity does not come out of nothing; it is a result of a multitude of various changes, mostly technological, over a long period of time. Therefore, early warning signs are an extremely important factor for the long-term success of organizations, and there is a strong pressure to proactively look for weak and strong warning signals at all times.

In the transformation from today's factories to smart factories, more sustainable business models are required, which include increasingly automated, robotized and digitalized systems. Flattened organizational structure is becoming a characteristic of digitalized organizations, and means less managerial hierarchy, which entails a bigger control span and more empowerment, that is, involvement, of more knowledgeable employees. Global presence means conducting business worldwide on one hand, but on the other, it means also being exposed to global technological changes and having the advantage of interacting with business partners, in order to sense weak signals on time.

Digitalized organizations (smart factories) have increasingly been establishing an early warning system for identification and response to weak signals, making it organizationally functional by including all systems and employees in the early warning system process. They make use of this system when doing strategic planning and performing strategic decision-making. In addition, experienced managers should be able to sense weak signals intuitively as today's unrealistic ideas might be a reality in the future. Hence, in an ever-changing business environment of

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emerging digital economy and with the evolution of smart industries, the strategic approach of managers, with a rapid and instant response system and an early recognition of most critical factors of emergency, is much required to avoid strategic surprises.

This paper has several limitations, which have to be taken into account. First, the research has been conducted using the case study of one company that is utilizing technological advancements in order to sustain its competitiveness. However, in order to increase the objectivity of the study, we have included a sample size of four managers, based on the purposive ideographic sampling approach (Luthans and Davis, 1982). Second, the research is focusing to the technological threats, in particular the technologies enabling the development of the Industry 4.0 concept in one company, while threats of different nature are also emerging and could have even stronger impact to business environment, such as social change. One such example is the recent problem of the ageing workforce in Europe, which is about to grow from 85 million today to more than 132 million in 2060 (European Commission, 2017).

Both future researchers and practitioners may benefit from our work and propose the changes in human resources management practices that would improve working environment for older workers (Connell *et al*., 2015), particularly in the automotive industry. Particularly, the practitioners may use our model in order to treat the trend of ageing workforce as an early signal, taking into account the specific country-level conditions in a particular industry. For example, the company may treat the ageing workforce trend as identified, and according to our model, the management could proceed to screening, appraising and responding to this important societal change. In addition, the model could be adapted to the issue of ageing workforce in different industries, such as furniture production (Radović, 2013) and mobile e-services (Johansson and Andersson, 2015). Finally, our model is based on the intuition, but recently, a new trend emerged that is focusing to analytical-based decision-making (Thirathon *et al*., 2018). Therefore, future research should also focus to both conflict and coherence between intuitive and analytical-based decision-making.

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