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How to leverage distributed data to create an HR 4.0 platform to support workforce management? A proposed solution based on three industrial contexts

Juliana Salvadorinho[a]*, Paulo Pintor[b], José Moreira[b,c], Marlon Freire[d], Nelson Ferreira[d] Leonor Teixeira[a,c]

[a] *Department of Economics, Management, Industrial Engineering and Tourism (DEGEIT), University of Aveiro, Aveiro, Portugal*
[b] *Department of Electronics, Telecommunications and Informatics (DETI), University of Aveiro, Aveiro, Portugal*
[c] *Institute of Electronics and Informatics Engineering of Aveiro (IEETA), University of Aveiro, Aveiro, Portugal*
[d] *Bosch Termotecnologia, S.A., Aveiro, Portugal*

Abstract

The digital paradigm, or more commonly called the fourth industrial revolution, brings 4.0 technologies with the capacity to generate a high amount of data. Most companies already did some digital implementation, however the information generated is dispersed, and there is, therefore, an advantage in aggregating it in single management platforms. The human factor, which is being put aside of this digital revolution, is the focus of this paper. It is intended, using three different organizational contexts, to initiate the conceptualization of a platform that makes use of data from different sources and that aggregates them converging in human resource management KPIs. It is extremely pertinent that the human factor is placed at the center of technological innovation, as its retention becomes preponderant in a paradigm that is so volatile. Thus, this paper demonstrates the data sources observed in the three contexts, finds some functional requirements for the conceptualization of an HR 4.0 platform, such as, through the triangulation of methods, the key performance indicators that must be displayed in it.

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* Corresponding author. Tel.: +351 234 370 261; fax: +351 234 370 215.
E-mail address: juliana.salvadorinho@ua.pt

1. Introduction

Industry 4.0 paradigm has been opening the door for multidirectional frameworks to ensure a more effective engagement of the workforce with organizational strategies and performance goals. The concept associated with this new paradigm involves a number of new technologies, including the Internet of Things (IoT), Cloud Computing, Big Data Analysis and Artificial Intelligence (AI) [1], as well as Augmented Reality or cooperating robots and smart human resources management processes. With this emerging industrial context, new technologies are being integrated into the shop floor, causing an unprecedented increase in the number and heterogeneity of data sources [2]. In turn, this diversity of data sources also generates huge amounts of real-time data streams. On the other hand, this digital phenomenon introduces systems of greater complexity due to the automation and interconnection of all its elements. Organizational and process understanding will be included into core qualifications of industrial workers, therefore people will have to be able to recognize elements of the whole production system, understand functions and relations within the system and still acquire the capability to predict systems behavior [3], [4].

This new paradigm gives human resource (HR) managers the possibility to increase efficiency through emerging technologies that can automate processes, resulting in smarter and more efficient HR teams, using the Smart HR 4.0 concept as the key motivational driver. But to get there, company leaders should be forward-thinking about their HR strategies, and always mindful of their employees, and an agile workforce is an essential necessity in the growing scenario of automation of smart HR management systems platforms regarding attrition, well-being and engagement of the employees.

Industry 4.0 promotes worker mobility which constitutes a challenge for HR management. In this way, companies can take advantage of the great diversity of data that they have spread out in several sources (some of them unstructured), but that when integrated can promote the knowledge of the level of engagement, well-being and motivation of the employee. Thus, and since there are many data sources related to HR management and these are dispersed in the organizations, the Smart HR 4.0 supports the idea of aggregating the data (automatically), processing them, and generating key performance indicators (KPI) that must be displayed to the manager for decision-making.

This paper aims to study and conceptualize an integrated HR 4.0 platform able to collect and integrate data (on human resources) from multiple and distributed data sources in order to provide visualization dashboards of KPIs related, for example, to wellbeing, performance and motivation of its human resources. For the requirements elicitation phase three different industrial contexts (one is in the metal-mechanic sector, another in the chemical sector and yet another operates in the retail trade of furniture and lighting articles) were studied. Thus, to initialize this conceptualization, the companies' data sources were determined, some functional requirements were already described and the KPIs (based on the data sources) were found and later modeled.

2. Literature review

2.1 The challenges of human resource management in I4.0 environments

The digital paradigm, also known as Industry 4.0, can be recognized as a widespread digitalization and linkage of production processes, beginning in the customer’s order, advancing through production processes, to downstream product services. Thereby, self-organized value-creation networks are supposed to be in the lead of deep changes in economic interactions [5]–[7].

This phenomenon was prompted by the development of Information and Communications Technologies (ICT) and its technological basis is settled in smart automation of cyber-physical systems with decentralized control and enhanced connectivity between the physical assets and computational capabilities, using IoT [6], [8], [9].

Enterprises are the main contributors to a country's economy and they are immensely dependent on their capacity to answer to their clients’ expectations while maintaining a competitive advantage on their market [10]. Even though Industry 4.0 tools may involve a substantial investment and a superior level of expertise, it emerges to be more flexible since it decentralizes information and decision-making [10], [11].

Industry 4.0 contributions will profoundly shift the way people work and control their activities. However, companies will still benefit enormously from the participation of human resources and their ability to make decisions, since this will have an impact on the improvement of processes’ operational performance [12]. Furthermore, they are considered to be invaluable resources, since they coordinate, solve problems, handle increased complexity and flexibly

adapt to challenging work environments [13]. Having knowledge of information systems' potential within the scope of the digital paradigm and recognizing the importance of the human factor in this scope as well, it is therefore necessary companies to present integrated systems that, through the exposure of KPIs, can develop a greater and better decision-making regarding their organization's human resources.

Human-centricity is considered to be a crucial factor of Industry 4.0 and is an approach that has been developed around Operator 4.0 concept [14]. With the digital paradigm, companies face the emergence of human symptoms induced by a new and innovative work environment. Workers have to face autonomy of actions, excessive demand, as well as adaptation to new responsibilities and roles within the new processes [4], [15]. All this can result in mental stress and demotivation [15]. Besides, the increasing complexity of many jobs is inevitable, including a growing need for cross-functional work and partner networks between companies. In addition, new job profiles that combine skills, particularly technological skills, are being developed [4], [16]. Thus, for more effective and agile management, it is essential that existing human resource data be aggregated in this direction, for better allocation and even, recruitment of staff. Business leaders are focusing on applying effective HR management, developing new ways of working, promoting a learning culture in the organizational climate and creating innovative strategies for the future that can directly contribute to the successful implementation of Industry 4.0 [17].

2.2 About Human Resource 4.0

The so-called Operator 4.0 is represented by qualified operators who carry out their work with the support of machines, interact collaboratively with robots, advanced systems and sensors and, in addition, use augmented and virtual reality. All of this promotes the exploration of the benefits of enabling technologies to understand production through context-sensitive information [18]. These trusting and interaction-based relationships between humans and machines exploit not only machines' strengths and capabilities, but also encourage operators with new skills in the sense of seizing the opportunities are being conceived by technologies 4.0 [19].

As cited in [20], "You do not only gain competence through formal education but also through life-long learning", and many organizations understand the upgrade of competencies as crucial in order to develop competitive advantage, having the same time an upgrading in company's performance, indorsing knowledge at all organization's levels.

Retention is an intentional move by an organization to build an environment that keeps employees for a long term, because if they leave the company (for competing organizations, for example), they take with them the knowledge and internal secrets obtained from their previous organizations [21], [22].

2.3 The importance of data sources integration and KPIs

Industry 4.0 focuses on digitization, automation, adaptation, decentralization, optimization, production customization, human-machine interaction, value-added business and services, and system integration to meet the needs of coordination, cooperation and collaboration [23]. In this way, the integration and implementation of IoT at the industry level generates a huge amount of data volumes (Big Data). This data, when collected and subsequently analysed and processed can reveal hidden patterns, undiscovered correlations, market developments, customer trends and other useful information that can help organizations to be informed of the real state of your business, in order to enable better decisions [9]. Thus, has been stated by [13], "the incoming technology-driven paradigm shift of Industry 4.0 will increase digitization, automation and communication" and information systems and technologies will be positioned as pivotal for the achievement of enterprise interoperability and traceability [8].

Enterprise Systems goal is the integration of data and business processes throughout an organization. For this to happen, enterprises must be in continuous communication and cooperation [24].

The KPIs emerge to make visible the information derived from the processing of data dispersed in different sources throughout the organization. A KPI is a measure used to demonstrate the business effectiveness in specific objectives and targets. Therefore, they can be applied to recognize poor performance and the improvement potential [25], [26].

3. HR 4.0 platform: Study and conceptualization

3.1 Goals and methodology

This work goal is centered on the conceptualization of a platform capable of automatically collecting data from different sources in a company, while processing them according to KPIs considered to be preponderant in HR management. Firstly, the data sources were identified, and some functional requirements were also obtained, then, to determine the most important KPIs, a triangulation of methods including literature analysis, documentation analysis, focus group (in the context of the organizations studied), was applied. This approach uses several data collection methods on the same phenomenon [27]. In this information collection the following methods were used: documentation analysis (where documents were provided by the pilot companies), focus group (with members from human resources area of the organizations involved), and literature analysis. In the end, it was possible to establish an indicators matrix oriented to the human resources management capable of representing the reality of the three pilot companies used in this study. Note that in this work, due to space restrictions, only a few are shown in table 1 with their description. Meanwhile, to move along with the conceptual modeling of those that would be the platform's outputs, some of these KPIs were illustrated using multidimensional models, applying the document flow model notation for this purpose.

3.2 Results and discussion

3.2.1 Data Sources

In this initial point, the platform must gather data from different systems and datasets, i.e., ERP systems, medical systems, sensors and machines, and others unstructured and flat files. It is restricted to each company who will provide data to the platform. A brief description of each data source is provided: (i) Manufacturing Execution System (MES) is the system that gathers all the information about factory workers, machines, resources and materials for scheduling and assigning the workers, equipment and materials needed for the production process; (ii) Enterprise Resource Planning (ERP) are systems designed around a single, complex and multi business process, and defined data structure (schema) that typically has a common database; (iii) Medical Data (MED) is the system that collect medical data from the employees in the company, and can also provide information regarding the work conditions of the employees; (iv) IoT devices are the sensors, machines and other system that have a human-machine interaction; (v) Time attendance is the system that collect data related to workers companies daily time schedules (a time and attendance system enables an employer to monitor their employees working hours and late arrivals, early departures, time taken on breaks and absenteeism); and (vi) Flat files are stored data, also known as a text database, storing data in a plain text format and without any structured interrelationship. It covers many text files formats including, i.e., Excel, .CSV among other text files. Therefore, while not really a system, flat files are still very much used through all organizations, to collect, store and analyze information not available in any other system.

3.2.2 Functional requirements

A system requirement indicates an ability or condition that must (or should) be fulfilled, also may specify a function that a system must perform or even a condition a system must accomplish. The system requirements are divided into functional and non-functional requirements [28]. The functional requirements represent an interaction between the user and the system's interface. The non-functional requirements describe what the system needs to perform the applicable requirements. These requirements need to fulfil the needs of the different companies and to achieve it, meetings were held with all those involved. From these meetings, we all agree that the functional requirements must focus on permissions levels because different users might have different views. The application must allow the user to create KPIs and features to create dashboards and filter information, among others. Considering non-functional requirements, the first essential requirement is that the platform needs to be autonomous and independent from the companies' information systems. Other non-functional requirements include the periodicity of the data update and the responsibility of each company for these updates, and the need for security already revealed.

3.2.3 Human resources data: key performance indicators

As already mentioned, the triangulation of methods was applied to determine which would be the most relevant KPIs to display in the platform. For the initial consideration of a set of KPI referring to the HR management, an exploratory analysis of the literature was carried out, based on [29]–[33].

After identifying the most crucial KPIs targeted by the literature for this purpose, meetings (focus group) with partners were held, to proceed with the validation of the indicators, as well as to integrate others existing in the organizations involved and not present in the literature. Based on this, it was possible to compile a set of relevant KPIs, classified into three categories: **Employees**, **Contracts** and **Company Advertising**. A more detailed explanation of the KPIs in each category is given in the next subsections.

Table 1 summarizes some of the indicators (among others that are part of this solution) that will appear in the HR4.0 platform, since they are distinctive for the promotion of employee engagement.

Table 1. Some key performance indicators of HR 4.0 platform

Category	Key Performance Indicator (KPI)	Description
Employees	Absence rate	Division of the number of working days in which the employee was absent by their total number of working days
	Employee productivity rate	Capacity of growth in terms of production of human capital
	Suggestions per employee	Division of the total number of suggestions given by the total number of employees
	Democratic talent management	Task satisfaction (time taken by the operator to find a task somewhat repetitive)
	Training effectiveness	A company's scale can be 1 to 3, where 1 is unfinished, 2 is ineffective and 3 is effective
Contracts	Turnover rate	Division of the number of employees who left by the average number of employees
	Voluntary turnover rate	Number of employee-led resignations as a percentage of the total resignations
	First year termination rate	Division of the number of employees that have voluntarily left the company before working for 12 months by the total number of people that leave within the same year
	Female to male ratio	Division of the number of employees of one gender by the total number of employees
	Average time stay/employee tenure	Division of the sum of all tenures by the number of full-time employees. This should be equal to the division of the sum of all tenures in that particular role by the number of full-time employees in that job role
	Ratio women managers	Division of the number of women managers by the total number of managers
	Work rotation	Number of times people change tasks
	Average age of retirement	Calculation of the average age of people who leave the company to retire
	New hire 90-day failure rate	Percentage of employees that leave the company in the first 90 days and the percentage of employees that pass this so-called probation period

Employees

The category of KPIs associated with employees includes indicators ranging from biographical data, assiduity, productivity, training, engagement, value of suggestions per employee, democratic talent management to potential assessment.

Regarding **biographical data**, these focus on the most basic information that companies hold about their employees, ranging from name, marital status, date of birth, the distance they live from work, whether employees have children and even if they are studying. When it comes to **assiduity**, it is important to know the level of absenteeism in the company, as well as the cost it entails. In relation to this vector, there is still the value of overtime that is exercised by employees. As is normal in any company, the level of **productivity** must be constantly observed, being essential for making potential procedural improvement decisions (this level can concern both the operator, as well as a department or area). Focusing now on **employee training**, for each one of employees it will be important to

keep the data of the training hours, the levels performed, as well as their performance in each of them. In addition to this, its overall effectiveness should be monitored in a concrete and practical environment, namely using, for this purpose, interviews, forms or even direct observation, the cost of this training should also be considered as essential, as well as the percentage of employees trained. **Engagement** is the state with which a certain person shows himself with vigour, absorption and dedication in its workplace and is strongly involved in improving performance (if the engagement score is high). This indicator has already validated scales, and one of them is that of the Gallup consultant [34], which its questions includes many of the dimensions inherent to the organizational climate (necessary to assess the context external to the employee). Very related to engagement, comes the **suggestions per employee value**, since, theoretically, the higher the level of engagement, the greater the employee propensity to contribute with suggestions for the organization overall improvement. **Democratic talent management** is a concept that was introduced by the involved companies and refers to the satisfaction in the scope of the task that the employee performs. In parallel with this, it is intended to ascertain the time that an employee takes to consider a task, somewhat repetitive. The **potential assessment** encompasses the potential for career development of a particular employee. Here it is intended to establish a common code to the companies that shows: the employee's ability to move up the position, his / her suitability for the current job and the need for training.

Contracts

The category of KPIs related to the contracts that the company executes with its employees comprises three large groups of indicators, those related to the **admission of employees**, those related to the **dismissal or contract terminations** and those related to the **diversity in the company** (related to people and tasks performed by employees).

Regarding **employee admissions**, the time it takes to hire, the quality and cost of hiring need to be monitored. Here, it is also important to understand, whether the functions are filled by existing staff at the company (who moves up the ranks) or if these people are appointed by the workforce. Not much related to admissions, but because the quality and/or quantity of the workforce is at stake, mention that the cost of the workforce and the revenue per employee must be calculated, to understand if there is a balance between how much it is costing all employees and the value they are producing (if it has contributed with profit to the company).

Now focusing on **dismissals and contract terminations**, it is important to assess turnover within the company (staff turnover), whether total, voluntary, involuntary and even unwanted. In addition to turnover, a metric widely used in business is the new hire 90-day failure rate, which only differs in time from the first-year voluntary termination rate. As there are also companies that promote employee retention until very late (in terms of age), it may be interesting to monitor the average age of retirement. Regarding **diversity**, which can be within the people of the organization or even in terms of the tasks performed, it is important to highlight the female to male ratio, the ration of female managers, types of operators (if they are temporary or from the company) and the work rotation (ratio that refers to the average task turnover for an employee).

Company advertising

For the **company advertising category** there is the staff advocacy score, which refers to how much employees identify with the company to the point of recommending it through word of mouth. This indicator is given through a question: ‘How likely is it that you would recommend this company as an employer to a friend?’. It uses a scale from 0 to 10 and converges on the result of: 1- Advocates (score 9–10) are loyal and enthusiastic employees who will promote you as a potential employer; 2- Passives (score 7–8) are satisfied but unenthusiastic employees who are vulnerable to competitive offerings; 3- Detractors (score 0–6) are unhappy employees who can damage your brand and prevent growth through negative word-of-mouth. This indicator is calculated based on the subtraction between the percentage of employees who are advocates and the percentage of employees who are detractors.

3.2.4 Technological Perspective

This section presents a conceptual model of the system organized as a multidimensional data model. The Dimensional Fact Model (DFM) notation [35] is used and the data is represented under the metaphor of a multidimensional cube. The models presented are, respectively, **absence**, **training**, **hiring**, **end of contract** and **turnover** multidimensional models, representing only a part of the whole solution.

The fact table in the first model (Figure 1) is **absence**. The employee dimension represents the personal data (name,

birthday, etc.) and data aggregations by type of contract (permanent or temporary), employee category, gender and level of education, team, department and cost centre. The motive dimension indicates the cause of absence based on a list of motives associated with codes, which will depend on the company. This model will be used to compute the KPIs about the absence rate and absence costs, as well as to compute the employee engagement index, employee productivity rate, and advocacy score. Some of the information present in the employee's dimension, like contract type, will change over time, and there will be a need to hold a historical. The model in Figure 2 is related to the employees' **training** actions and will help understand what training the employees received, and the costs and the duration of those actions. This model has a fact table (training action) and four dimensions - action, area, entity and context. The entity and context dimensions represent who is responsible for the training and whether it is performed in the company (internal) or elsewhere (external). The action dimension holds the details of the training action and the area dimension denotes the subject of the training, e.g. marketing or publicity. The employee dimension is the same as in the previous model and so, the details are omitted. The date dimension will have the start date and the end date. This information can be used by HR managers to understand the outcomes of the training actions and to compute KPIs the Training effectiveness, Training costs and Percentage of employees trained.

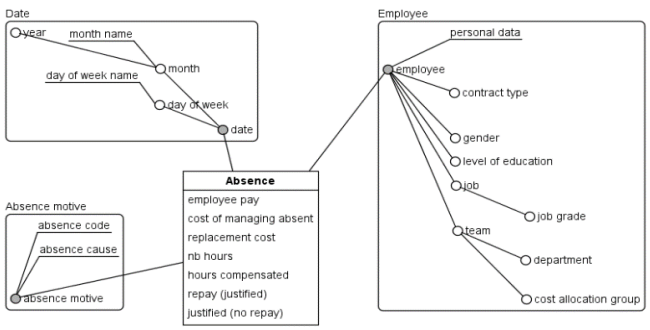

Fig. 1. Absence multidimensional model

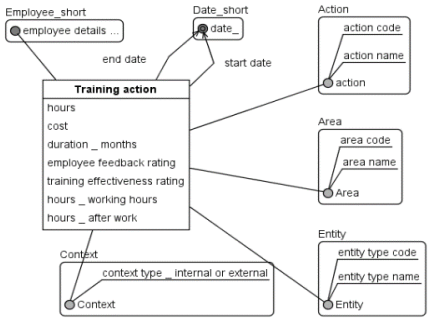

Fig. 2. Training multidimensional model

The fact table **hiring** in the model (Figure 3) has the information about the costs of hiring an employee, including advertisement and other related costs, and is used to compute the KPIs percentage of cost of the workforce, Quality of hire, Time to fill/Time to hire. The companies need to understand the costs of hiring but also need to realize how/why people are leaving. Figure 4 and Figure 5 helps to explain why a contract ends and the turnover rates. They will answer the following KPIs: turnover rates, average time stay/employee tenure, average age of retirement, new hire 90-day failure rate, first year voluntary termination rate and work rotation. The fact table **end of contract** (Figure 4) has no measures and so, it is used for counting events using filters on the dimension's tables. The fact table **turnover** (Figure 5) has the measures needed to compute all the turnover rates. These two models give the big picture about employment ends and can be compared with information about hiring to understand the company's behaviour regarding employee's contracts and rotation.

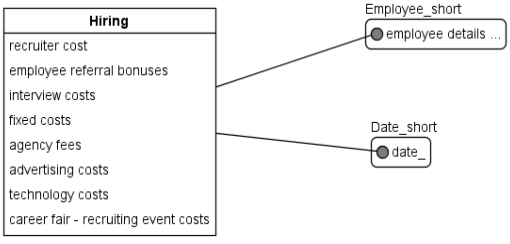

Fig. 3. Hiring multidimensional model

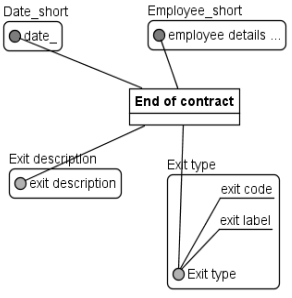

Fig. 4. End of contract multidimensional model

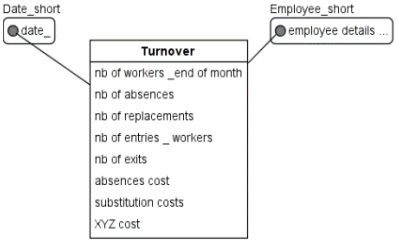

Fig. 5. Turnover multidimensional model

4. Conclusion

Industry 4.0 brings connectivity and interoperability, with the adoption of cyber-physical mechanisms. The capture of data in real time is the basis of this paradigm, and with it comes the need to treat these same data (processing with data analytics), to obtain information capable of sustaining a more decentralized decision making. The companies involved in the scope of this project already take advantage of various systems that are able to collect data from the shop floor. However, they will now be able to leverage that data to manage their workforce, as it hides patterns of employee engagement and attrition that, when known, can contribute to better management of human capital. The digital context implies a total reconsideration of HR management, where in addition to new skills curricula being explored, a whole learning culture must be promoted by managers. The data sources found within the organizations that participated in this study, properly aggregated, and processing their content, are enablers of a more digital and agile HR management. In such a volatile context and where the realization of new skills is in demand, retaining the workforce and the organizational knowledge created within it becomes imperative. Information systems are then the point of contact between the data entered and/or collected and the information generated for decision-making within an organization and, therefore, it is imperative to monitor the condition of the human factor and make it centre of technological innovation.

This paper presented the first version of the requirements specification of an integrated platform for Human Resource Management 4.0. The methods used to collect information included research on applications and related work in HR management, research on key performance indicators in the same context, focus group and data collection from organizational documentation.

As part of the future work, it is intended to develop the modelling of the software architecture, as well as to standardize the data of the three companies participating in this study.

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