Digital Marketplaces for Industry 4.0: A Survey and Gap Analysis

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Abstract. Industry 4.0 is the called 4th technological revolution, where digital and physical marketplaces and manufacturing technologies converge to enable smart manufacturing and factories of the future. This paper presents an overview of a representative set of marketplace platforms available to support supply chain processes underpinning Industry 4.0. We develop a gap analysis of existing marketplaces assessing their ability to support Industry 4.0 requirements. Finally, we position our survey and gap analysis in the context of the European Union's Horizon 2020 programme, in particular on the Digital Automation call topic addressing the theme of collaborative manufacturing and logistics.

Keywords: Industry 4.0 · Supply chain · Digital marketplace · Collaborative technologies · Gap analysis

1 Introduction

Corporations are steadily moving to a mode of competition and collaboration coined "Industry 4.0", which uses Internet technologies, sensors and big data to develop industry solutions. The shift in computing towards the cloud, the wide availability of information services that can be remotely accessed, and the new business models enabled by the software as a service paradigm, are the catalysts for the vision of Industry 4.0 to become operational. For the full accomplishment of this vision, it will be essential that digital marketplace mechanisms are created to support the service ecosystems arising from the multitude of market players and service portfolios.

In this paper, we present a survey of digital marketplace platforms with a potential towards supporting Industry 4.0 initiatives. In particular, this survey aims to provide an assessment of service marketplace design and configuration platforms that will enable the dynamic evaluation and composition of hundreds of thousands of potential candidate services towards developing Industry 4.0 solutions. We develop our gap analysis taking into account the context of the European Union's Digital Automation call topic aimed at developing technologies towards enabling Industry 4.0 collaborative networks within European organisations [14]. The survey and analysis conducted in this paper have the following research questions, which outline the future directions for developing an Industry 4.0 solution:

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1. What concepts, techniques and services of Industry 4.0 are available in current marketplace environments for collaborative supply chain systems?
2. How can a digital marketplace platform address capability gaps in traditional approaches to collaborative supply chains?
3. How can digital marketplace tools impact the business, organisational and Information Technology (IT) architectural approaches within collaborative supply chains?

This document is organised as follows: Sect. 2 discusses background and related work, Sect. 3 presents the research method and our gap analysis. Section 4 includes the discussion on the research questions' answers, and finally, Sect. 5 concludes the paper and presents key findings.

2 Background and Related Work

Industry 4.0 moves towards efficient manufacturing systems, augmenting the automation of the processes and actors involved in Industry, and aiming at a highly efficient response to internal and external events, seeking for resilience and adaptive systems [2, 4]. The EU's Digital Automation call topic, supported by the Horizon 2020 programme, presents a vision towards innovations on collaborative networks across manufacturing value chains within Industry 4.0 [14]. Particularly, the vision presented requires development to support Small and Medium Enterprises (SME) participation and collaboration with large Original Equipment Manufacturer (OEM) companies in the supply chain comprising management, control, manufacturing, and logistics capabilities [14]. The main objectives of the call involve the development of technological means for a resilient, flexible and event-responsive procurement process, capable of coping with a dynamic environment providing automated reconfiguration within the supply chain processes [14]. The research involved in the EU's Digital Automation call topic includes addressing the development of solutions able to optimise and facilitate collaboration among different stakeholders involved, including supply clusters, companies, factory machines and objects [14].

Within EU's Digital Automation call topic, a marketplace refers to the tool that will support the entire supply chain life cycle processes, which will be used by both demand side (requestors) and suppliers when participating in the bidding process, and will enable suppliers to form temporary coalitions, towards fulfilling complex call bids where multiple suppliers might be needed, with a strong focus on enabling SMEs to participate in the marketplace.

3 The Supply Chain Digital Marketplace

Ten platforms were selected and analysed as the representative platforms of today's marketplace. The selection criteria include the relevance of the platform, where the platform should be utilised by at least 1000 members, however, most of the platforms surveyed have millions of users [7–10, 12, 15–17, 19, 21]; a second selection criterion

involves the platform's support for business-to-business (B2B) transactions, where companies on both sides of the digital marketplace (requestors and suppliers) participate, rather than only individual users; a third aspect considered was the identification of the platform as an eProcurement one; finally, the marketplace selected should be of high relevance and impact within its domain area, measured by their geographical span (regional or worldwide, but not local). These criteria were defined to eliminate the risk of selecting platforms that might be tackling different objectives to those relevant to Industry 4.0, in such a way that each of the platforms is indeed a tool that supports the supply chain management cycle in a virtual environment.

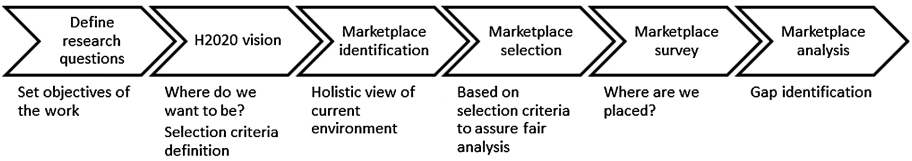

Fig. 1. Gap analysis method applied

Figure 1 outlines the method we utilised to carry out the work presented and define the criteria summarised above. The first step comprised defining the research questions to set the objectives of the analysis. Secondly, we explored the European Union's Horizon 2020 program's vision (H2020), in particular, the Digital Automation call topic towards Industry 4.0; this exploration provided the context of the study and enabled the recognition of the most relevant elements that are needed to develop a working Industry 4.0 solution. Based on the exploration conducted, we were able to define a selection criteria for the platforms to be surveyed accordingly. The third phase gathered information on available marketplaces, where more than 20 trading platforms available to the European market were identified; however, a fourth phase was dedicated to selecting only those platforms that met the criteria defined in the second phase. This was done to avoid creating an unfair comparison and analysis, where there was the risk of including marketplaces out of the scope of the research objectives. Examples of platforms that were left aside include those with little visibility within its domain area, with less than 1000 members, or very low impact and functionalities, and no intention to connect businesses but instead support a peer-to-peer (P2P) approach, as these platforms would provide an exaggerated and not necessarily representative gap. Finally, we proceeded to analyse the selected platforms in terms of the vision identified, thus, we were able to gather insights on the situation of the current representative digital marketplaces and identify the existing gaps.

Table 1 presents an analysis of the platforms surveyed. The analysis considers the platform's capabilities with regards to collaboration in supply chains and production networks, and their functionalities to support a working marketplace. This gap analysis intends to identify the limitations of the current supply chain marketplace solutions towards accomplishing the EU's Digital Automation call's vision.

The first column in Table 1 shows the area in which each platform works; the relevance of pointing out the industry area in which each platform works resides in the

Table 1. Surveyed marketplaces overview. Marketplace platform labels: (UG) UK Government Digital Marketplace (https://www.digitalmarketplace.service.gov.uk/), (AL) Alibaba (https://www.alibaba.com/), (CB) CloudBuy (https://www.cloudbuy.com/), (IM) IndiaMart (https://www.indiamart.com/), (OW) OFweek (http://en.ofweek.com/), (HA) Haizol (https://www.haizol.com/en), (IZ) Izberg (http://www.izberg-marketplace.com/), (AB) Amazon Business (https://www.amazon.com/b2b/info/amazon-business?layout=landing), (MI) Mirakl (https://www.mirakl.com/mirakl-marketplace-platform/), and (TH) Thomas net (http://www.thomasnet.com/).

Marketplace/Category		UG	AL	CB	IM	OW	HA	IZ	AB	MI	TH
Area	IT services	✓		✓							
	Retail/wholesaler		✓	✓	✓			✓	✓	✓	✓
	Industrial			✓		✓	✓				✓
	Services			✓					✓		✓
SME participation	Supported	✓	✓	✓	✓						
	Not supported					✓	✓	✓	✓	✓	✓
Type	Sellers listing			✓					✓		✓
	Sellers & buyers listing	✓	✓		✓	✓	✓				
	Online shop to third party suppliers							✓		✓	
Evaluation	Internal		✓		✓			✓			
	External	✓					✓		✓		
	None			✓		✓				✓	✓
Security	Existent			✓							
	None explicitly	✓	✓		✓	✓	✓	✓	✓	✓	✓
Connection to external systems	Supported							✓		✓	
	Not supported	✓	✓	✓	✓	✓	✓		✓		✓

discovery of the existing degree of coverage, especially for the industrial and services areas, therefore the area in which more development is needed can be identified. The majority of the platforms work with retail and wholesalers, with no specific domain set; second place is taken by those platforms that are focused on a particular vertical domain. Only one of the platforms surveyed is dedicated exclusively to a specific domain area, which is the case of the UK Government Digital Marketplace, dedicated to IT services such as cloud computing offerings. Finally, it can be identified that not all of the platforms support a service marketplace, where business or individuals can offer or request services and parts. The analysis reveals a capability coverage gap in digital marketplaces available specifically for the aerospace and automotive domains.

The EU's Digital Automation call topic has SMEs as one of the main beneficiaries, this is why it is important to analyse the platforms surveyed in terms of SME participation support. The participation of SMEs seems to be a growing area in the marketplace; however, it is not yet fully supported by the majority of the digital marketplaces, as Table 1 shows. This symbolises an opportunity to cover the gaps to provide wide support for SMEs within an important domain besides general trading.

Among the platforms surveyed, three types were identified; the first type is formed by those platforms where the functionality supports products or services listing only for

suppliers; the second type of platform identified enables either buyers or contractors to list their requirements as well as suppliers to list their capabilities and interact with each other in a two-way communication, and the third type found is composed of those platforms that provide technological means to create a digital marketplace managed by one of the users, which then will coordinate and be responsible for an internal marketplace available to third party suppliers, called "the sellers". This is the only form in which a kind of Virtual Enterprise (VE) is supported; however, it is not clearly treated as one. There is also no support in any of the platforms for the management of constructs resulting from the assembly of VEs or cooperation to fulfil the same bid. The type classification is of relevance because this category allows us to identify the most utilised model within digital marketplaces, hence, it could be known where is the major gap to cover, and identify where are the emerging developments going as a perspective.

One important issue to solve when talking about VE formation is to consider how the suppliers will be evaluated to form a viable VE. Within the platforms analysed, not all of them have procedures to evaluate if a supplier is reliable or not; this is presented in Table 1. Normally, the evaluation is done by the same platform (internal evaluation) or the users awarding rates to identify ranges among the available suppliers (external evaluation).

When dealing with bids, sensitive information will be required, such as details of the bid, which might include strategic information, designs not yet ready to be published, contact information from contractors and suppliers, etc., which makes information security and governance information a major concern in the digital marketplace. Among the platforms reviewed only one prioritises security, where Payment Card Industry Data Security Standard (PCI-DSS Level 1) is claimed to be used, and the "buyers" that use the platform are governed by rules selected to limit information access. The last category evaluated is the platform's functionality to connect to external devices, platforms or things, which can be translated in Internet of Things (IoT) capabilities, which is a core functionality towards Industry 4.0. In this category, only two of the platforms surveyed are able to connect to the major e-Commerce solutions, and none considers a connection to physical devices. IoT seems to be an open area for development within marketplaces solutions.

3.1 Marketplace Gap Analysis Towards Industry 4.0 Aims

Six main processes of the supply chain aligned to the EU's Digital Automation call topic could be identifiable: Procurement, Engineering, Manufacturing, Delivery, Risk Evaluation, and Monitoring [6]. The marketplace analysis presented in Sect. 3.1 reveals there are some processes not currently available to use from the marketplaces surveyed, and for those processes supported, there is no coverage within the same marketplace platform.

The Procurement process supports the registering of a company to the platform, either to be a contractor or a supplier, this process also supports the functionality to publish a tender or offer a bid, where both sub-processes mentioned are basic functionalities supported by the majority of the platforms. One process not yet available is VE identification and formation [6]. The contract management process, part of the

Procurement process, is supported by some of the platforms analysed, however, most of the time it is offered in a rudimentary form, with no support for custom/personalised legal features.

Another identified process is called Engineering; this provides guidance and availability for the first statement of the requirements towards initialising the Manufacturing process. As part of the Engineering process, a capacity planning sub-process is contemplated, where data models describing the production plans are required to assess and allocate the capacity of individual participants within a VE to fulfil a bid. The capacity planning is not supported by marketplaces yet, this reflects another example of a VE management process not supported.

The Manufacturing process is currently left to be managed by each supplier on their own, without support from any platform. A production planning process and a scheduling process is required [6], in such a way the suppliers and contractors could monitor each and every phase of the manufacturing process, accompanied by risk management tasks on each phase. This is a helpful functionality towards optimising collaboration and resources.

The Delivery process is covered by the majority of the marketplaces nowadays, but it was found to be very limited. The main functionality towards delivery is to let the involved entities know the date of delivery, and then some marketplaces implement a satisfaction or evaluation (ratings) survey once the delivery is completed. The logistics planning is not supported for VE management, and to a lesser degree, it is supported for multi-vendor situations.

Finally, some major Industry 4.0 processes within the manufacturing value chain are novel, such as the automated risk evaluation and monitoring, where this last one if existent, is supported only by manual updates in the majority of the marketplaces. An overview of the findings towards those Industry 4.0 processes and the platforms

Table 2. Designed Industry 4.0 Value Chain processes covered by available marketplaces

Industry 4.0 value chain process	Sub-process	Covered by marketplaces available
Procurement	Registering company	Yes
	Publishing tender	Yes
	Offering bids	Yes
	Forming consortium	No
	Contract management	Yes
Engineering	Capacity planning	No
Manufacturing	Production planning	No
	Scheduling	No
Delivery	Delivery forecasting	Yes
	Logistics planning	No
	Satisfaction evaluation	Yes
Risk evaluation		No
Monitoring		Partially

Table 3. Summary of the marketplaces gap analysis

Category	Expectations	Gaps
VE management support	Support for VE creation, recommendation for VE formation, evaluation for potential suppliers to form a VE, management as if participants were a single company	There is no model to support VE in digital platforms
Logistics management	Availability of capacity planners, contract support, production planners, operational and delivery tools, with resilient, scalable, automated solutions	Logistics management, including delivery details, are approached separately, out of the digital platforms, or even without IT interaction
Monitoring	The main expectation is to monitor in real time with connection to physical items, such as sensors, PLCs, etc.	Monitoring is carried out mainly by manual updates. No IoT for supply chain monitoring is available integrated within a collaboration platform
Risk evaluation	Risk evaluation will be an inherent functionality of the supply chain management, automated and efficient	Risk evaluation if any, are most of the times done outside digital platforms with separated and isolated technological tools

surveyed mentioned above are represented in Table 2 and summarised in Table 3. The gaps presented offer an overview of the areas in which opportunities and challenges to address exist. IoT appears as the major gap to address, with special attention required on protocols and models designed to cover this gap.

4 Discussion and Future Directions

The main goal of the current study was to identify existing gaps within digital marketplaces towards enabling future initiatives for industry, especially those focusing on supply chain management. Although there are research outcomes available to support Industry 4.0 characteristics [1, 11, 18, 20], we evaluate the extent to which existing digital marketplaces are already involved with those developments, and identify those areas that require focus towards enabling a working Industry 4.0 solution to support the whole supply chain management processes.

The first question in this study sought to determine what Industry 4.0 concepts, techniques and services are available in current marketplace tools to support Industry 4.0 collaborative supply chain systems. Industry 4.0 represents a new approach in the value chain, integrating an organisation and control merged with technologies and digitalisation [3]. This paper has found that generally, Industry 4.0 requirements are not fully supported in existing platforms. IoT is not implemented in the majority of the value chain stages of the surveyed platforms, cyber-physical-systems (CPS) are not present, and digitalisation is limited only to the online identification of products or services facing the customer, but not for communication between any of the factories'

elements. We also identified that actions are triggered based on manual updates, rather than automated information sharing.

With respect to the second research question, it was found that digital marketplace platforms can address the gaps of traditional approaches in collaborative supply chain by developing protocols and models to cover the gap in the integration of IoT with Industry processes, and developing unified technologies that might support the complete digitalisation of the physical factory and machinery, for which CPS communication and IoT are important parts. We believe industries will need to begin the path to digitalisation underpinned by cloud services, machine-to-machine (M2M) communication standards, embedded systems, and the introduction of new business models. In a separate layer, governance and security issues will arise linked with the new architectures, including challenges in handling Big Data.

The third question driving this research was how digital marketplace tools can impact the business, organisational, architectural and technology approaches within collaborative supply chains. Industry 4.0 will support the development of new business models and new methods of creating value chains, and will widen the marketplace for SMEs by adopting a model in which small-scale batches of products and custom products and services will be competitive against larger enterprises [3]. These benefits will be enabled because of the increased levels of control, micro-work specification and customisation from Industry 4.0 approaches [5].

An example of how digital marketplaces can impact business models is when the information details obtained from a product distribution is at a new deeper micro-work specification level compared to the information that could be obtained before marketplaces from Industry 4.0; this information could provide value when shared among the organisational structures and roles of the companies or collaborators, generating a change in the processes carried out. Organisational aspects will change due to the increased dynamism of the industry, both within and across companies, and new information could be obtained in real time. Together, these developments provide important insights into the steps ahead for Industry 4.0. Making use of the most innovative and recent technologies might not be enough without assuring the business and organisational models reflect the most effective way of doing business.

The industry of the future will reduce the burden involved in traditional supply chain processes, and will also create new opportunities to provide a highly dynamic environment with substantial benefits for businesses. The Industry 4.0 for the supply value chain required platform will support IoT, CPS, and smart technologies (i.e. Semantic Web Standards) that can enable M2M communications within supply chain systems and provide Industry 4.0 solutions. Future research will concentrate on the investigation of Industry 4.0 use cases, with a particular interest in the challenges, benefits and drawbacks.

Future direction also includes the development of several tools and technologies in the context of the Decentralised Agile Coordination Across Supply Chains (DIGICOR) EU project, coined as a platform that will consist of open tools and services for European companies requiring working within collaborative networks supporting Industry 4.0 activities [13].

5 Conclusion

This paper presented an overview of a representative set of marketplace platforms available to support supply chain processes underpinning Industry 4.0, and a gap analysis of existing marketplaces assessing their ability to support Industry 4.0 requirements, positioned in the context of the EU's Digital Automation call topic addressing the theme of collaborative manufacturing and logistics. Results of this paper revealed digital marketplace platforms have not yet moved completely from supporting simple collaboration approaches, where, for example, B2B models are formed by only one company on each side, and although there is research covering different aspects of more elaborated collaborations, such as VE formations and SMEs clusters, we believe there is still significant work to be done in relation to digital marketplaces to incorporate more advanced virtual organisation capabilities such as dynamic search, assessment, selection, and formation of coalitions. The limitations in existing digital marketplaces arise primarily due to a considerable gap between VE research adoption and its dissemination into commercial practice.

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