Digitalisation for organisations in industry 4.0: A working example

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Abstract. Digitalisation and Industry 4.0 is changing the landscape of traditional industries and how they operate. Regulation, sustainability and staff shortages are challenging companies to alter their behaviour and business processes. It is now becoming essential for small to medium size enterprises (SMEs) to adapt to this change. This paper showcases how digitalisation can help with these new requirements by examining a case study with specific interest in collecting, monitoring and analysing data. The application was created for an SME registered in Ireland, and it will be used to showcase the difference between normal coding and low code development in the creation of these apps. This comparison is important because low code development will become essential for organisations in order to create novel IT-based approaches that will be used for the digital transformation of their specific business. Along with describing and reflecting on this process, we will also explain how this application is linked with the Sustainable Development Goals (SDGs) and how companies can integrate these goals in their business and IT choices.

Keywords: Digitalisation, SDGs, Low-code development, Model Driven Development, DIME, Requirements

1 Introduction

"Service science is the study of service systems aiming to create a basis for systematic service innovation combining organization and human understanding with business and technological understanding to categorize and explain the many types of service systems that exist as well as how service systems interact and evolve to co-create value" [1]. This was the single clearest explanation of understanding service science in a business setting that has been published. As Industry 4.0 continues to evolve at a rapid pace, the creation of an area in organisations that covers both IT and the management of people and goods is essential for digital transformation to occur. In order for this to become a reality, it is imperative to put in place supports for practitioners so that they understand, plan and execute their projects through visual guidance. Adequate visual guidance means are canvases and diagram-based frameworks implemented as IT tools [2]. This support is essential as the requirements needed

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for building and managing various projects are changing quickly due to the progressive digitalisation, and solutions sometimes need to be executed with out-of-the-box thinking [3]. This is essentially the same concept as organising a correct business model canvas (BMC), which has been outlined as follows [4,5]:

1. How key components, functions or parts are integrated to deliver value to the customers.
2. How those parts are interconnected within the organization and throughout its supply chain and stakeholder networks; and
3. How the organization generates value, or creates profit, through those interconnections.

To steer organizations in these uncertain times, it is imperative to support their continuous decision-making accordingly [6]. Combined with the extremely important Sustainable Development Goals (SDGs) [7], this is the important addition needed in order to produce an organisation that embraces the change induced by digital transformation and digitisation in general. This embrace can lead to the use of sustainable development practises to create digital sustainability practises. An example is a link between building communities (SDG goals) and communicating across stakeholder ecosystems (essential for digitisation transformation to occur) [8]. Understanding how the SDGs can be applied to an organisation can be quite easily misunderstood. Companies are sometimes unsure whether the SDGs are relevant for them, and thus they do not apply any sustainable practises in their business. Linking business practises that are currently already in use with the external SDG goals can achieve new out-of-the-box thinking, leading to more efficient business operations while also expanding the sustainable reach of that organisation.

Domain specific languages (DSLs) and platforms for knowledge management [9] created in this way can serve as tools to provide companies with an easy approach to adopting service science, sustainability and expanded business practises into their methodology. The work described in [10] showcased the DSL approach for combined risk and sustainability analysis: there, a DSL was created to support a specific kind of workshop where organisations work in conjunction with business consultants [10]. Extending the research of Ryan [9], we develop an application that digitalizes a core part of a company's (Elite Engines Limited (Registered in Ireland) [11]) everyday activity concerning data collection, management and reporting. We examine how this process was decided, the link with the SDGs, and the difference between low code development and creating an application with java. This was the company's first interaction with digitalisation. It arose from the new requirement of reporting certain datasets to a regulatory body. This exemplifies how the need for data and its reporting and management are evolving and increasing in the Industry 4.0 era. Furthermore, this paper will examine this new regulatory requirement, analyse what the organisation needs to do in order to implement such a protocol, and how this process is going to be executed from the company's perspective.

2 Case study workshop

From our previous research [9] emerged that five steps need to be addressed in order to produce a DSL and an application that provides value to a company. These are 1) business understanding and business logic, 2) knowledge harvesting, 3) analysis of the new/evolved needs, 4) set up of the decision support, and 5) decision making using the decision support method or system. These five steps are shown in Fig 1 as the lifecycle of the DSL in action. These same 5 steps are, however, very general. In fact they can also be used to analyse any business problem and produce a set of solutions that can be further analysed and improved before implementation. This reflection and optimization are essential as they will guide the organisation to make better and more informed decisions. In fact, the main contribution is

having access to a structured process and guidance that will elicit the generation of the correct data and information that its members need in order to take these decisions in an informed and documented way. The same approach can be used to create a DSL, especially because the DSL can be easily altered as the organisation changes and improves.

The company chosen for this workshop is Elite Engines Limited (registered in Ireland). In a previous paper [11] we examined their sustainability issues and created a workshop and simple DSL to organize this part of the company in a more coherent fashion. Now they had a number of issues in need to be rectified, including new reporting guidelines that they must adhere to. This new reporting required the collection of information and data that they did not previously collect or store. Essentially, digitalisation was being forced upon the company by newly introduced regulation. Every SME must actively examine how they can adopt such an approach moving forward in the current business climate. Following the guidance by the 5 steps, we designed how to solve these issues by developing an application, and we did it in two distinct application development paradigms: with traditional coding practices such as Java [12], and also adopting a low code development approach using the DIME [13] Integrated Modelling Environment. Both approaches will be examined in more detail in this paper.

In the next section, we will discuss the requirements of the new reporting regime for the business and we will concurrently target some of the SDGs that need to be addressed.

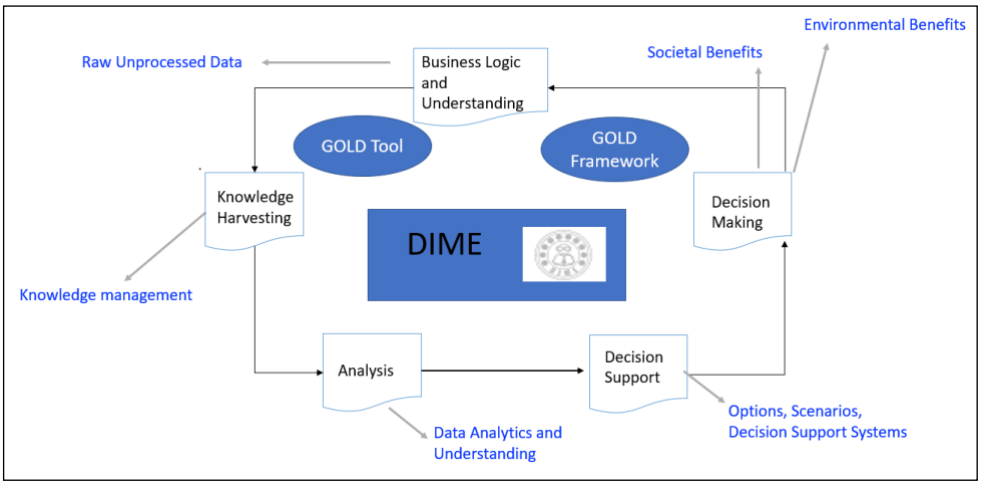

Fig 1. The five steps of the DSL design and use – using DIME

2.1 Business logic and understanding

Understanding the business and the business logic is the first and most important step. Essentially, it encompasses eliciting the issues that the organisation needs to address and also the identification of the correct business rules. In this case study, Elite Engines Limited examined the most critical and important aspects that have changed within their organisation within the last six months. A key novelty is the new regulatory requirements that the company needed to address: the Dublin City Council (DCC), an Irish Government organisation, required that all the exported automobile engines to be tracked from the source supplier to the forward destination and customer. The purpose of the new requirement is to ensure that the engines are of good quality from a sustainable perspective. Examining and analysing why such requirements are now being forced on companies, it appears that the various government organizations introduce such protocols and tracking approaches in order to enforce key

sustainable perspective areas. Examples are linking current company key partners and current customer relationships with the more enhanced sustainable model of sustainable partners, sustainable customers, responsible customers and end of life products. Also the previous paper addressed sustainability, but inside out: there, a company decided to move from the current towards a more sustainable business setting, and we compared business model canvases vs. sustainable model canvases [9].

The two SDGs targeted by the DCC are:

SDG 8 – Decent work and economic growth
SDG 12 - Responsible consumption and production

With this information, we developed a guided workshop where we examined the areas that the business needs to address from a digitization perspective in order to meet this requirement. A key issue found within the business was the lack of methods of collecting data. This hindered them being proactive with meeting the new regulation requirements. According to the WPP report 2020 [14], data volumes, which are already enormous, are set to further explode in the near future. The IDC predicts that 175 zettabytes of new data will be created annually by 2025, up from 33 zettabytes in 2018 [15]. Part of this growth is due to SME's beginning to join other industry 4.0 participants in the realisation of the power of data, utilising it to the benefit of the company for marketing, business growth, automation or in order to satisfy regulatory requirements such as this.

2.2 Knowledge Harvesting

This step focuses on the macroscopic aspects of the issue, like the varying inputs and outputs that need to be considered. This includes examining what data will need to be collected and stored and what application should be used for such an approach. In this task, the consultant (us) and the client (Elite Engines Limited) jointly created and listed the important data points to be collected in order to track and report suppliers from the new application to be developed. From the workshop emerged that three main areas need to be considered: tracking incoming engines (engines purchased), outgoing engines (engines sold), and a stock list for inventory currently on the books. The various data attributes that needed to be collected and stored were decided as well: the engine type, the supplier, quantity, date, hand cranked status and automatically generating a specific stock keeping unit (SKU) number for the various engines. It was decided to collect and store the information for reporting purposes through a simple mobile application.

2.3 Data analysis and understanding

2.3.1 Java code application

The mobile application was created using Java [12] and android studio with one account for user authentication. This Elite Engines Stock Management application can be seen in fig 2. It is a normal app that can be deployed on a mobile device, it is easily accessed like other applications on a mobile device. This app provides the data collection (it was not collected or stored before) and the access to the said data for the organisation.

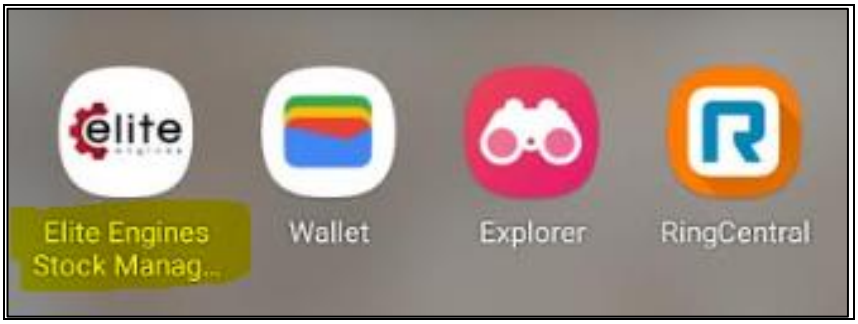

Fig 2. The mobile app

Once the user accesses the application on their mobile device, the Edit/Add Stock page appears. This accepts and stores data such as engine, quantity, supplier, hand cranked status, price, date and whether it is incoming or outgoing (see Fig 3). A SKU number is generated automatically and given to each engine type so that it can be easily traced. It is important to assign a different SKU number to engines of the same type but from a different supplier, so that the origin of the engine could be easily traced for the requirement of analysing and reporting.

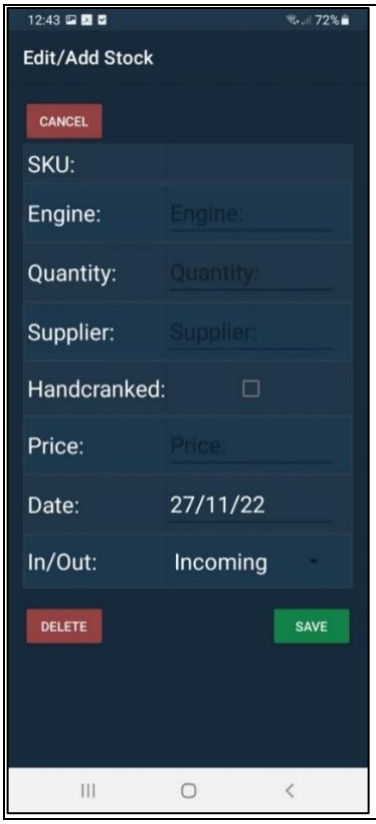

Fig 3. Edit/add stock screen

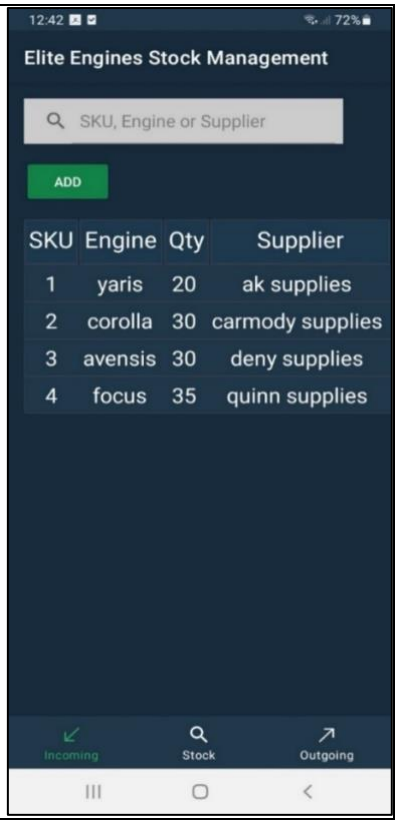

Fig 4. Engines incoming screen

The data is then stored on the application's incoming page (see Fig. 4) showcasing the type of engine, quantity and supplier along with the specific SKU numbers that were generated when the engine was input to the application.

A third screen deals with the engines that are being sold to clients (see Fig 5). The sales update the inventory on both the app and the excel sheet linked to the mobile device and an external One Drive. This is an important piece of data to collect as it also acts as a packing list for the client, that otherwise would need to be generated manually. This packing list is used in logistics for the transportation of the container. The supplier details of each engine are also recorded so that the requirement of reporting this segment of data was easily captured and stored via a unique SKU number generated automatically by the application.

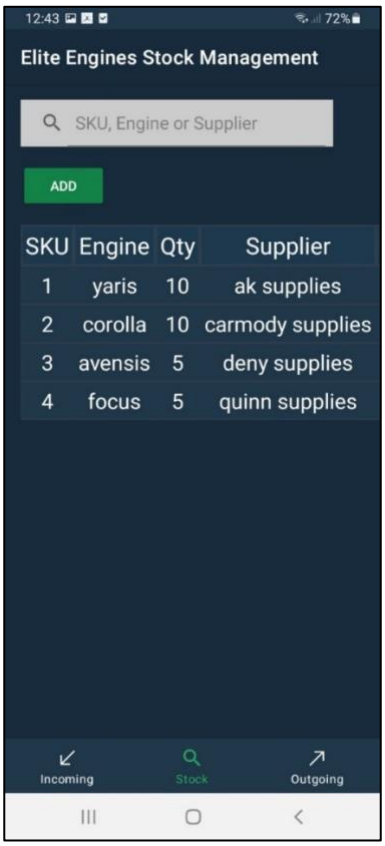

Fig 5. Engines outgoing screen

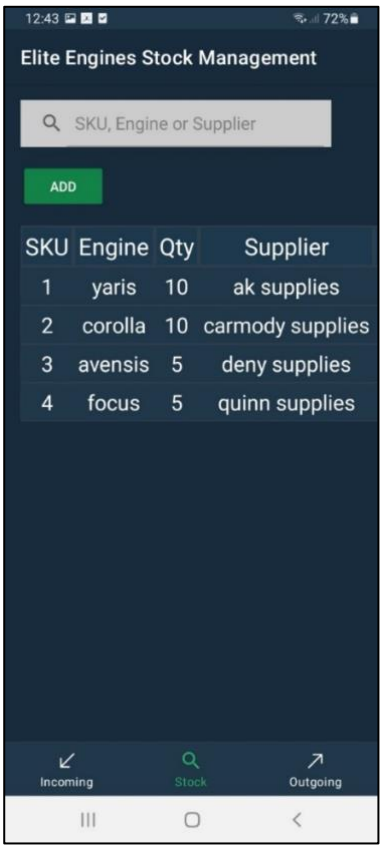

Fig 6. Stock and inventory screen

Finally, a screen for the stock and inventory is available (see Fig 6), providing an up to date inventory for the organisation. This data is also copied to an external excel sheet where we create customised dashboards to better showcase the data to the organisation.

2.3.2 Low code application

The application just described was created using Java, meaning that a non-programmer technician would not be able to easily create or modify such an app. Therefore, we decided to replicate this application using a low-code development environment, DIME [13], the

Integrated Modelling Environment [16] as discussed in [9]. This low code application allows users to model all the needed aspects from a design standpoint, so that many more users are enabled to create bespoke applications that can be tailored to the organisation's needs. The power of this low code application paradigm has been described in [17], [18] and [19].

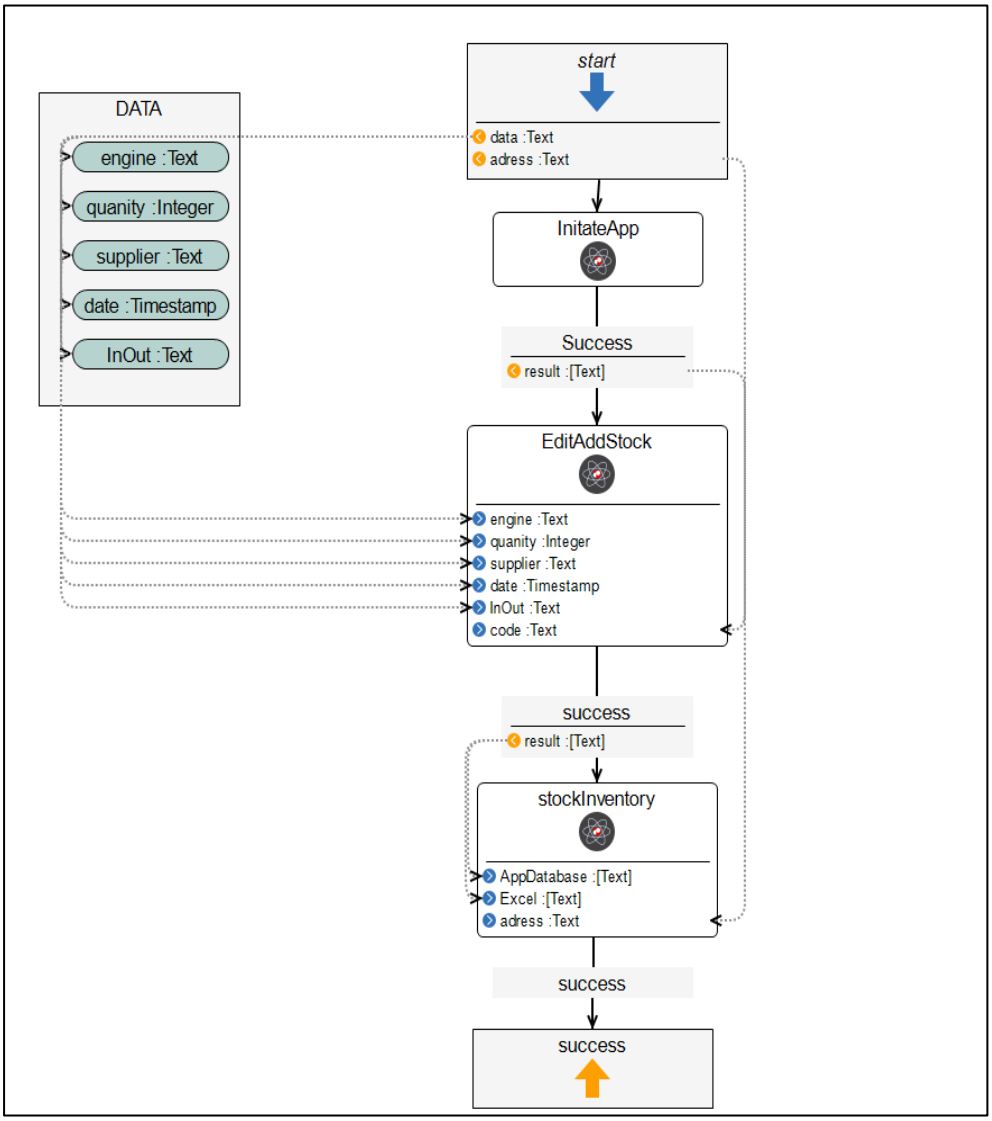

Fig 7. Subprocesses of the application for entering data

In this paper, we show the subprocesses that would be needed for the just described application, as discussed earlier in the workshop. As shown in Fig. 7, the design of the application consists essentially of interaction processes which are executed by the user when using the application. Due to the graphical models, the process is easily understandable and executable by domain experts that are not programmers. To modify the process, the designer uses predefined drag-and-drop components called SIBs (Service-Independent Building blocks) that are reusable modelling components [20]. It was observed that the main benefit

of using such a low code environment is the reusability by the organisation, which can tailor specific (object oriented) elements as the business evolves and acquires new forms of data.

Comparing building the application in java with this low code approach, we can see that in the low-code paradigm domain experts in the company would have the capability of building their own application, without requiring the knowledge and ability of general coding and script writing that is inherent would in the direct coding approach. This provides the organisation with the ability to change and alter the requirements needed for the app at a moment's notice, which increases the reaction time within the business. This is a critical advantage in this Industry 4.0 smart age.

2.4 Decision support and decision making

The data collected by the app is copied to an excel sheet stored on the phone. We then used OneDrive clone to copy the data to a central location for storage and analysis, where we can also create some decision supports on top of this data. Samples of the data (pseudo data) are shown in Fig 8a and Fig 8b. As more data is collected. dashboards can be developed to better showcase the inventory to the organisation. As Dublin City Council requires the identification of the suppliers to be sent to them after every container is exported, we created an easily exported pivot table: it is generated automatically and sent directly to the council with very little manual input. These pivots can be seen in Fig 8c. This is the starting point for data analysis and decision support for the organisation.

SKU	Engine type	Quantity	Supplier	Type	Date
1	yaris	20	ak supplies	Incoming	01/11/22
2	corolla	30	carmody supplies	Incoming	02/11/22
3	avensis	30	deny supplies	Incoming	02/11/22
4	focus	35	quinn supplies	Incoming	02/11/22
1	yaris	-10	ak supplies	Outgoing	20/11/22
2	corolla	-20	carmody supplies	Outgoing	20/11/22
3	avensis	-25	deny supplies	Outgoing	20/11/22
4	focus	-30	quinn supplies	Outgoing	27/11/22

Fig 8a. Copied data from the incoming/outgoing app screen.

SKU	Engine type	Quantity	Supplier	Date
1	yaris	10	ak supplie:	20/11/22
2	corolla	10	carmody s	20/11/22
3	avensis	5	deny supp	20/11/22
4	focus	5	quinn supp	27/11/22

Fig 8b. Copied data from the stock and inventory screen

Supplier name	Supplier address	Contact info
ak supplies	unit 1, unitd metals, dock road, Limerick	061. xxxxx
carmody supplies	Currachase, Kilornan. Co. Limerick	061. xxxxx
deny supplies	unit 12, apk business park, Ballysimon road, Limerick	061. xxxxx
quinn supplies	Currahaven, kilcglass, Co. Galway	069. xxxxx

Fig 8c. Pivot automatically created from the data to be sent to the regulatory body.

3 Conclusion

In this work we showcased the importance for SMEs to adopt service science and digitalisation in general. This is now becoming essential as regulatory reporting with data is required by Government organisations. Is it simply not sufficient anymore for companies to report what data they currently have at their disposal and not actively engage with new IT-supported business practises to obtain and store the relevant data that they need. It is also extremely important that this data is accurate as discrepancies can lead to incorrect report filings, which could lead to incorrect reporting at Government level.

There is a need for these processes to be available to all organisations: whether they have IT capabilities or do not possess these capabilities, the need is the same. We showed that an application could be created either by utilising low code development or a normal java code-first implementation. It emerged that adopting a low code approach is essential for the wide uptake, as not every business has the capability to create a bespoke app. Having a development infrastructure in place that uses low code, organisations can use the shared DSLs and ensure that the data being collected and stored is correct, the application is fit for purpose for that specific organisation and changing the application to new needs is not out of scope for the business team. This is an important capability, as Industry 4.0 is changing rapidly and so do the needs in terms of data and applications at the disposal of SMEs.

This DSL and low-code approach has also secondary benefits in the areas of sustainability and reduction of manual labour, which are both a serious threat to organisations at present. The SDGs can be used as sparkle for achieving and executing well managed business practices, either autonomously or with the help of external thinking and consultants. In many cases, the same level of quality and optimization would not have been achieved at the organisational level without the explicit goals and the availability of new-generation IT. The goals can be used as guidance in order to enhance business practices that might not have been achieved or recognised if this specific sustainability perspective had not been considered. We are aware that the results of examining one specific area of business (the supply of used engines) and its new needs cannot be generalized directly to other sectors or organisations. However, showcasing that utilising low code development within business settings can be done can set a new precedent in how organisations adapt to the ever-changing landscape of Industry 4.0 and even 5.0. Thus, part of the outlook is to further apply the approach and extend the research to other areas that would have a much larger scope to contend with. We argue that a new generation of IT tool support, such as DSLs and low code development environments, are essential as the involved stakeholders are usually either IT experts or business experts, and they rarely have expertise in both. We believe that once integrated with a knowledge-based platform, such DSLs will make the IT supported workshop experience, guided by experts or simply guided by the tool, become a possibility for multitudes of companies and organisations.

References

1. Maglio, P.P., Spohrer, J. Fundamentals of service science. *J. of the Acad. Mark. Sci.* 36, 18–20 (2008). https://doi.org/10.1007/s11747-007-0058-9
2. Steffen, B., Möller, F., Rotgang, A., Ryan, S., Margaria, T. (2021). Towards Living Canvases. In: Margaria, T., Steffen, B. (eds) Leveraging Applications of Formal Methods, Verification and Validation. ISoLA 2021. Lecture Notes in Computer Science, vol 13036. Springer, Cham. https://doi.org/10.1007/978-3-030-89159-6_7

3. Steffen, B., Steffen, B. (2021). Asking Why. In: Margaria, T., Steffen, B. (eds) Leveraging Applications of Formal Methods, Verification and Validation. ISoLA 2021. Lecture Notes in Computer Science, vol 13036. Springer, Cham. https://doi.org/10.1007/978-3-030-89159-6_4
4. Chesbrough, H., 2010. Business model innovation: opportunities and barriers. Long Range plan. 43 (2-3), 354- 363. Retrieved May 30, 2021from https://www.journals.elsevier.com/long-range-planning.
5. Osterwalder, A., Pigneur, Y., 2010. Business Model Generation: a Handbook for Visionaries, Game Changers, and Challengers. John Wiley & Sons.
6. Steffen. B , Ryan. S and Margaria. T: Towards *Living* Decision-making Based on Risk Analysis in Manufacturing Supply Chains. Presented at IMC-37, the 37th International Manufacturing Conference Athlone, Ireland, Sept 2021.
7. SDGS (n.d.). SDGS United Nations. Retrieved July 05, 2021, from https://sdgs.un.org/goals.
8. Verizon, 2019 Data Breach Investigations Report, USA, 2019, https://enterprise.verizon.com/ resources/reports/2019-data-breachinvestigations-report.pdf
9. Ryan, S. (2022). The Qualitative background of why a DSL knowledge based platform is needed in the context of Sustainability. In. Electronic Communications of the EASST Journal vol 8. DOI http://dx.doi.org/10.14279/tuj.eceasst.81.1194
10. Ryan, S., Steffen, B.: Towards multi-perspective consulting in times of disruption. In: 2022 IEEE 46th Annual Computers, Software, and Applications Conference (COMPSAC). IEEE (2022)
11. Ryan. S and Margaria. T: Business Model Canvases and Sustainability – A Case Study on a SME. Presented at IMC-37, the 37th International Manufacturing Conference Athlone, Ireland, Sept 2021.
12. Arnold, K., Gosling, J., & Holmes, D. (2005). The Java programming language. Addison Wesley Professional.
13. Boßelmann, S., Frohme, M., Kopetzki, D., Lybecait, M., Naujokat, S., Neubauer, J., Wirkner, D., Zweihoff, P., Steffen, B.: DIME: A Programming-Less Modeling Environment for Web Applications. In: Proc. of the 7th Int. Symp. on Leveraging Applications of Formal Methods, Verification and Validation, Part II (ISoLA 2016). LNCS, vol. 9953, pp. 809–832. Springer (2016)
14. WPP Report (2020) Annual report 2020, available: https://www.wpp.com/investors/annual-report-2020 (accessed 01 Dec 2022).
15. Hawkins. O, (n.d), WPP Open Data 2030, available: https://www.wpp.com/-/media/project/wpp/images/wpp-iq/pdfs/wpp-data-2030-report.pdf?la=en [accessed on 30/10/2022]
16. Neubauer, J., Frohme, M., Steffen, B., Margaria, T.: Prototype-Driven Development of Web Applications with DyWA. In: Proc. of the 6th Int. Symp. on Leveraging Applications of Formal Methods, Verification and Validation, Part I (ISoLA 2014). pp. 56–72. No. 8802 in LNCS, Springer (2014)
17. Margaria, T.: Knowledge Management for Inclusive System Evolution. LNCS Transactions on Foundations for Mastering Change (FoMaC) 1(1) (2016)
18. Margaria, T.: Generative model driven design for agile system design and evolution: A tale of two worlds. In: Formal Methods for Industrial Critical Systems - 23rd

International Conference, FMICS 2018, Maynooth, Ireland, September 3-4, 2018, Proceedings. pp. 3–18 (2018), https://doi.org/10.1007/978-3-030-00244-2_1

19. Margaria, T., Schieweck, A. (2019). The Digital Thread in Industry 4.0. In: Ahrendt, W., Tapia Tarifa, S. (eds) Integrated Formal Methods. IFM 2019. Lecture Notes in Computer Science, vol 11918. Springer, Cham. https://doi.org/10.1007/978-3-030-34968-4_1
20. Margaria, T., Chaudhary, H.A.A., Guevara, I., Ryan, S., Schieweck, A. (2021). The Interoperability Challenge: Building a Model-Driven Digital Thread Platform for CPS. In: Margaria, T., Steffen, B. (eds) Leveraging Applications of Formal Methods, Verification and Validation. ISoLA 2021. Lecture Notes in Computer Science, vol 13036. Springer, Cham. https://doi.org/10.1007/978-3-030-89159-6_25