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Abstract: With reference to Smart Manufacturing and Industry 4.0 in general, a Digital Thread connects the data and processes for smarter products, smarter production, and smarter integrated ecosystems. While the tangible goods (products and production lines) are understood as needing a Digital Twin as an executable model, i.e. an in-silico entity on which to virtually explore design, production, quality, and lifetime maintenance, the immaterial goods like software and analytics artefacts are not yet treated on par. For the new Digital Thread paradigm to enter the mainstream, models need to be coupled with AI, ML and Data Analytics capabilities, to provide an integrated platform for automatic transformations, generations, and analyses that take advantage of the formalized knowledge about the immaterial and material entities. The formalized knowledge needs to include a variety of models together with Domain Specific Languages that use semantic types at their core.

The objective of this overall work is to develop a high-level architecture for a service-oriented Domain Specific Language (DSL) platform for knowledge management (KM-DSL) especially concerning sustainability and risk management. This paper will examine two strands of that work looking at business logic and understanding along with knowledge harvesting that concentrate on two case studies that will underpin future research to create the aforementioned DSL platform for knowledge management.

Keywords: Business Model Canvas, Requirements, Sustainability, Domain specific Languages, Knowledge Platform.

1 Introduction

In the new digital age of Smart Manufacturing especially in the context of Industry 4.0, there is a clear need for an effective description and formalisation of standards associated with the Sustainable Development Goals (SDGs) (SDG nd) along with risk standards and risk integration into an organisations approach to business. Understanding how it can be adapted into the organisations' early planning stage is also extremely important. It is true that there are set frameworks for organisations in manufacturing to follow in terms of the SDGs and risk standards and theoretical guidance on how to implement them, but these standards are only frameworks and overview models and merely act as a guidance for the thinking and approach that is required. They also are very simplistic as these frameworks alone cannot guide the organisation to anticipate the developments of technology and society which are evolving at a rapid pace which

change the relevant SDGs and risk metrics that are important for the organisation to consider at a specific time. SDGs and risks that are relevant to an organisation at the beginning may differ once the firm has fully established as a business. The method purposed to alleviate these constraints is to adapt the current Business model canvas (BMC) by integrating SDGs and risk into the planning process for businesses.

Our research examines the opportunities for organisations to have the capability of using this extended BMC that overlays blocks such as value propositions with sustainability goals and utilise these within a Domain Specific Language (DSL) platform. This combined with an integrated risk system into the business organistaion can alter the status quo currently seen. The idea is to identify and understand the main attributes that are important in the DSL architecture for companies to integrate SDG goals and risks and monitor these goals and risks through the lifetime of the company. This research demonstrates how the business model canvas can be used to identify relevant SDGs and also showcases how a risk integrated model can be used effectively in organisations. This analysis allows us to establish the important aspects that are needed in creating such a platform for users to increase opportunities to implement sustainable thinking and risk understanding along with monitoring these aspects through the lifetime of the company. This can be considered a form of the circular economy for business practises which is becoming very prominent in all industries.

Since the BMC by Osterwalder was published in 2010 (Osterwalder and Pigneur, 2010), it has supported companies with a strategic framework for brainstorming activities and thus has received increasing attention across the business sector. These activities have transformed how companies and organisations approach a new opportunity and guide the user to fulfil the project in a timely and coherent fashion by providing high level insights and strategies for management to consider. One of the fundamental drawbacks of the BMC is that if it is not fully understood by the participants, it can actually hinder rather than support business development. Outlined by (Casadesus-Masanell and Ricart, 2010), when a business model is fully understood it supports competitiveness and can align high level strategies with the goals of the organisation. A variety of key aspects can be contributed to a well organised BMC and these have been outlined by (Chesbrough, 2010; Osterwalder, 2004) as follows:

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.

As the so-called 4th industrial revolution is changing the overall landscape of many industries, it is essential that the business model canvases continue to evolve in order to provide benefit to such companies and organisations. This key issue has been investigated and potentially solved by the creation of a framework named the Global Organization Alignment & Decision framework (GOLD) (Steffen and Boßelmann, 2018). This frameworks outlines "a multi-perspective framework to support organizations in analysing their business context at multiple levels and discuss technological requirements as well as challenges for the development of modelling tools that support hierarchical integration of analyses and models as well as different

perspectives to converge on an organization-wide aligned business strategy" (Steffen and Boßelmann, 2018). Examining such a multi- level perspective approach in connection with a BMC provides businesses with the opportunity to enhance their current thinking in order to include other frameworks within their own approach to modelling their organisation.

As regulations and fundamental corporate thinking are changing at a rapid pace, two key areas affected is sustainability and the ability to measure and examine risk. This can be quite evidently seen throughout the world by initiatives such as the 17 Sustainable Development Goals (SDGs) and how they are being implemented by various states throughout the world (SDGS n.d.). It is important that businesses understand that debating whether to incorporate sustainability into their business strategy is no longer an option. This is clear especially when considering a value-driven approach to developing business strategies which can be vital to the long-term success for that company (Chladek, 2019). In order for this seamless integration to actually occur, we examine the high level architecture that would be needed for a tool-based support system for sustainability. This tool would guide and assist companies who begin their first steps in actually implementing some of the initiatives that have been outlined in the SDGs. We show that the sustainability prospective and framework that is currently stand alone can be integrated into a system that companies currently use, such as a BMC. Our current hypothesis is that by providing assistance to small and medium size enterprises (SMEs) and helping them to understand and adapt to sustainable opportunities by providing a step by step guidance system may lead to the SDGs being implemented within those organisations at a faster rate. We choose SMEs because they can be the most exposed to sustainability considerations, both internally and externally by their customers, and at the same time the most likely to have difficulty in analysis and adoption as it is the case for most best practices within organisations (IFAC 2013). Our analysis and case study may suggest that making a guidance tool available to the organisations, ideally a tool which can be embedded in their current BMC, would provide precious assistance in adapting their organisation to become more sustainable.

The same approach can be taken from a risk perspective. This can be seen from our previous paper where we examined how a new integrated tool support to allow for holistic and educated decision-making that is currently not available could be essential in future organisations where we showed its usefulness through a SWOT and risk analysis in manufacturing supply chains. (Steffen et al 2021). This paper essentially examined of how tools enable the proposition of rule-based frameworks, guided processes, and the connection of interlinkages between several frameworks and process steps. This systematic support allows for transparency and explicit alignment, which in turn support educated decision-making. The effect is to accelerate the learning curve for the specific canvases of choice, and to enable their agile modifications even in uncertain environments. In the paper it was demonstrated how the shortcomings of today's common single framework/single method analyses do not trigger the consideration of all the important known factors, and thus leave major blind spots.

It is important to understand that two main areas of work are being examined which are expanding or creating new easy to follow frameworks for risk and sustainability and gaining an understanding of how a multi perspective approach and canvas based approach for implementing these new or altered frameworks is needed. Currently it is a fair assumption to say that a companies or organisations are failing in actioning sustainability as there is no plan and

framework in place within the organisation (Morfaw 2014). This is seen most frequently in sustainability projects and alignment where for example a business tackles one area of sustainability, often by introducing a recycling program, switching to LED lights or installing solar panels and then consider themselves done and the objective ticked off. For the purpose of this paper, we will call such an approach the **"one and done approach".**

It is also important to underpin how this relates to the broader research at the Confirm research centre (Confirm) which can be observed in figure one below (Margaria et al 2021). The integration and interoperability among all these entities is a key challenge for the success of Industry 4.0 and this can be organised into three levels according to Margaria et al (2021):

1) Physical Integration, handling the connectivity and communication among devices.

2) An Application Integration, dealing with the coordination and cooperation among different software applications and data stores.

3) **Business Integration, covering the collaboration between different functions, processes and stakeholders.**
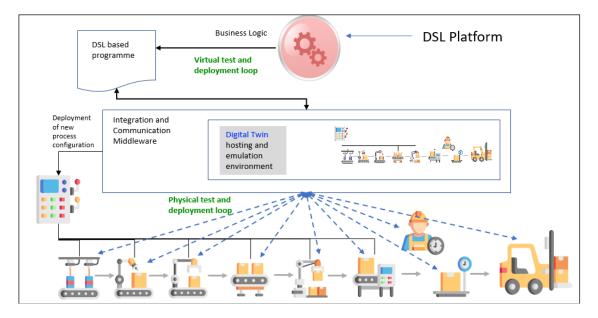

Figure 1: Confirm HUB CPS – The Reprogrammable Factory Vision (Margaria et al 2021)

This paper and its research sit at the intersection of **point three** (business integration) and business logic. This is the first area that needs to be addressed in the overall supply chain environment seen in figure one. With this in mind and now working along the GOLD paradigm introduced by Steffen and Boßelmann (Steffen and Boßelmann 2018), we look at the interdisciplinary collaboration landscape in Industry 4.0 as an instance of global organization

alignment and decision making. This is the basis for our research in terms of a qualitative approach. Examining the quantitative approach and in order for the above to become mainstream, a DSL high level architecture will need to be created and analysed so organisations can have a tool-based approach guidance system at their disposal.

To change the culture seen in organisations and provide assistance to help them adapt to a more circular economy as figure one depicts will in theory prove difficult to achieve. We want to change this approach not only in sustainability frameworks but to all business activities so they can essentially integrate a circular economy approach to everything they do within the organisation. A DSL is an approach that could help this issue but first and foremost and understanding and investigation into how sustainability and risk is currently completed by organisations is essential. This information and research will be gathered through case studies and recent paper publications. Once this is complete, we have an overall guidance approach to be implemented into a DSL knowledge platform for organisations to actually use.

2 Case Study – Sustainability and Risk – Canvas Based Approach to a DSL

Two main areas are going to be examined in this case study approach. Risk will be examined briefly with reference to a previous paper completed by us and sustainability in more detail from a canvas based approach. These case studies will be used as preliminary evidence of why a DSL platform is critical for all organisations to succeed in current Industry 4.0 levels of practise and provide us with valuable information that will be used to create the high level view of the DSL.

In regard to **Risk** and the qualitative approach of the research outlined, we can see how a new and integrated tool support that allows for holistic and educated decision-making can be instrumental in the decision making process for a business (Steffen et al 2021). This showcased a method of how to alleviate risk shortcomings by complementing the SWOT analysis for the purpose of managing and identifying risks continuously, which will be executed by utilizing a risk management system and approach within the canvas itself, which becomes a living tool which is constantly up to date and constantly consulted (Steffen et al 2021). "The concrete workshop results showed that each additional step led to additional inputs and reflections, and thus stimulated the participants to engage with areas that they would not have considered if guidance had not been given" (Steffen et al 2021). This was showcased through a canvas based approach and outlined how that approach will be able to mirror that in a DSL methodology. This will in the end reduce the need for expensive business consultants to conduct workshops or large organisations being brought in as they will have at hand an integrated tool support system that will do this automatically for them that follows a pre-defined framework which is very important.

This same approach can be mirrored in the **Sustainability** sector for companies, and we will outline in detail how this can be achieved by extending a previous research paper that was published in this area by the same author and outline how this can be mirrored in a DSL setting. Previously examined in an IMC paper and conference we have shown in a case study example that there was a clear need for an effective description and formalisation of standards associated with the sustainable development goals (SDGs) and the need for these to be adapted into the

organisations early planning stage (Ryan and Margaria 2021). It was shown how an in-depth analysis of the SDGs can easily be integrated into the companies' planning operations by providing a step by step approach for this integration and how this integration can be utilised by using a tool based approach. Our research also showcased how opportunities can be established in organisations by using such a BMC that overlayed blocks such as value propositions with sustainability goals and how these can be intertwined for business success. It also outlined how an in-depth analysis allows the user to establish effective opportunities to implement sustainable thinking right through the lifetime of the company. Examining in more detail, we want to extend this research to showcase how this approach can be mirrored and used in a DSL setting in order to help organisations in sustainable thinking and actions and move away from the one and done approach previously mentioned.

There are a variety of general frameworks available for sustainability, but none are comprehensive enough or provide any fundamental guidance for implementation. The same can be said with regard to the Sustainable development goals (SDGS, n.d.) which can be seen in figure two. The goal of this framework was to provide organisations and the general public with seventeen different segments that they can contribute to. It has been outlined that this has led to a tick box method that once a company achieves some form of sustainable action in one or two of the segments, it effectively checks out of the sustainable program that the United Nations has developed. What our research wants to achieve is to create a high level framework that fulfils a circular approach to this thinking.

Figure 2: UN Sustainable Development Goals: 1 – 17

In order to gather some preliminary data to consider, the paper first completed a 1st iteration of the business model canvas on a SME which can be seen in figure three. This outlined key areas that the organisation has under a group of different headings.
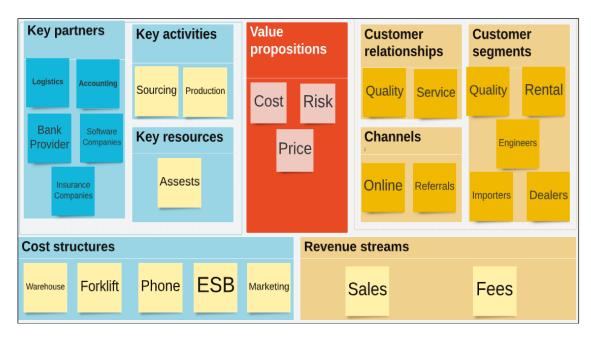
Figure 3: Business Model Canvas – 1st Itteration (Source: Ryan and Margaria et al 2021)

Once this was completed and a preliminary dataset produced, a second iteration of the canvas was created which can be seen in Figure four. The areas in pink were the sustainable areas that were identified from analysing the 1st iteration for sustainable contributions. We found that the new goals contributed to over 25% of the new business model canvas and provided new areas of business that had not been identified or understood before the workshop.
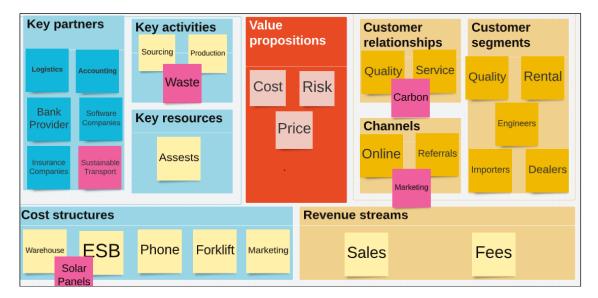

Figure 4: Business Model Canvas – 2nd Itteration with sustainabality prespective (Source: Ryan and Margaria et al 2021).

Once this had been completed, a third and final itteration was produced which can be observed in Figure five. This BMC has a much more integrated sustainability dimension than the original standard BMC. This third and final canvas is called the **Sustainability Model Canvas** (SBC) and it is the final product of the workshop (Ryan and Margaria 2021).
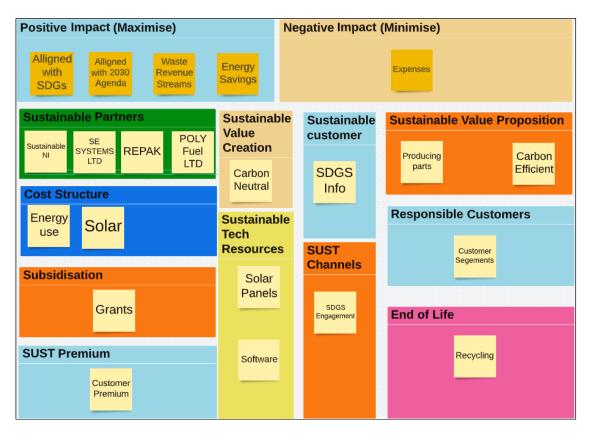

Figure 5: Sustainability Model Canvas (SBC) (Source: Ryan and Margaria et al 2021)

3 High Level Architecture of the DSL Platform

According to Visser (2008), "the goal of a DSL is to increase the productivity of software engineers by abstracting from low-level boilerplate code. Introduction of DSLs in the software development process requires a smooth workflow for the production of DSLs themselves. This requires technology for designing and implementing DSLs, but also a methodology for using that technology. That is, a collection of guidelines, design patterns, and reusable DSL components that show developers how to tackle common language design and implementation issues. Organisations are the domain experts so for them the ability to create a circular framework that works best for them is critical important for their business success.

Now that risk and sustainability case studies have been completed in a business setting, the learnings that can be taken from these need to be extracted and analysed so that a high level architecture can be created. From consultation with the case study participants during the workshop, five independent circular approaches have been selected that we feel are critical for a successful adoption of such a circular process and we will examine in detail each segment.

1) Business logic and Understanding:

In general, business logic / domain logic is a very important area to consider as it encompasses the correct business rules that organisations need to address and to a point if delivered correctly can determine how data and data ontologies are created, stored and altered as the organisation changes throughout its lifetime. Business logic can be understood in many different ways by various stakeholders and that it why it is important that a DSL methodology is completed. The general understanding from a software developer standpoint is that it is part of the solution that can execute user stories using domain objects as varying inputs and outputs. The domain is normally the problem space while the solution space contains the business logic, business rules, domain logic and domain knowledge which will come from a variety of stakeholders.

2) Knowledge Harvesting

This level will focus on the macroscopic aspects of production ecosystems, including business models, collaboration networks and supply chains to name just a few. In general, this part is going to be critical for automatically constructing large high knowledge bases from internal sources that the company processes. Taxonomic knowledge is already a huge asset for applications like search and analytics (Weikum et al 2019). Rules is another key element for advancing the intelligent behaviour of machines to capture invariants over certain kinds of facts in the form of logical rules (Weikum et al 2019). For example, a rule about a new product and their customers could state that the customer buying the new product actually purchased it as an early adopter in the life cycle – for it to be considered a new customer when the product was launched. This will make the data more accurate when collecting it and further down when analysing.

3) Analysis

This level considers the situated needs addressing the individual project in the context of the knowledge and risks as well as sustainability provisions and actions. Taking the data from the previous section of knowledge harvesting and analysing it through a business lens is imperative for the successful venture of a project being undertaken. In many businesses settings data analysis and the discussion of it can be skipped over far too quickly (Hair et al 2007). In order for this to be altered and for organisations to adapt to a more circular approach and understanding, the DSL will be integrated under the Confirm project outlined in figure one. Even though the main aim of that larger project was to target the application domain of advanced manufacturing including manufacturing analytics, the same approach can be taken for any other industry specific domain. Combining external data analysis languages such a R and integrating

them for organisation to use within a DSL purpose built platform for their specific domain will
change the status quo currently presiding in such companies and sectors.

4/5) Decision Support and Decision Making

Decision support and decision making: This level will combine the use of advanced tools in
operations research, AI, planning, diagnosis and recommender systems to generate schedules
and advice to key stakeholder users. These supports will be able to guide organisations in risk
and sustainability planning and examine best scenario practises and approaches to consider
before implementing it in real time form a business procedure point of view.

With these specific segments in mind, figure six is essentially the layout that the DSL knowledge
management platform will have for organisations to utilise. These 5 segments are
interchangeable and once the circular approach is complete it can restart in order to keep updated
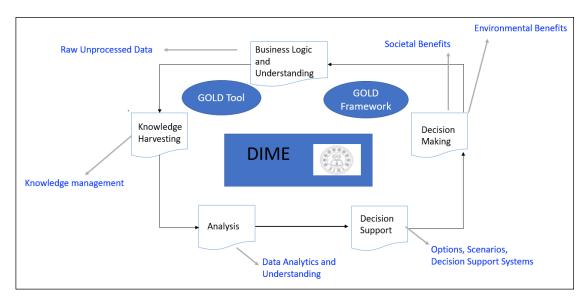and not form a one and done approach as previously mentioned.

Figure 6: DSL layout

Examining Figure six, we can observe at the centre of the figure is DIME which is a graphical
integrated modelling environment (Boßelmann et al 2016) which the DSL knowledge
management platform will be created on. This combined with the Gold Framework previously
mentioned and cited along with the Gold Tool itself (Steffen and Boßelmann 2018) will be the
main tools used for the overall project. This will cover the qualitative aspects by means of a
modified multi-level strategy modelling scheme based on the GOLD Framework. As a starting
point, GOLD in fact incorporates the most important frameworks and models used in businesses,
e.g. Porter's Five Forces, the Business Model Canvas, and the Value Proposition Canvas. It also
connects them in a consistent fashion throughout the organization's vertical and horizontal
levels, supporting a System-of-Systems approach that seems suitable for the situations we face.

These modelling elements could be transformed in a DSL for Industry 4.0 and then used to address at a concrete level a number of the questions that are addressed at a consulting level by the Fraunhofer platform the Confirm centre is going to roll out in Ireland.

This combined with the current work being executed in our group at the confirm centre which can be seen in Figure seven will also be utilised for overall data analytics and in general utilising the process model and data model with an overall Interface (GUI) will provide an enhanced DSL platform to organisations to leverage from the knowledge platform. (Margaria et al 2021). This figure showcases how the quantitative aspects could be dealt with by using data analytics methods such as R and if needed they could be complemented by the application of appropriate AI and Machine Learning techniques for aggregation of the requirements and constraints in a comprehensive ontology. This will provide analysis and visualization for adequate just-in time modelling support and feedback to decision makers regarding sustainability and risk within an organisation.
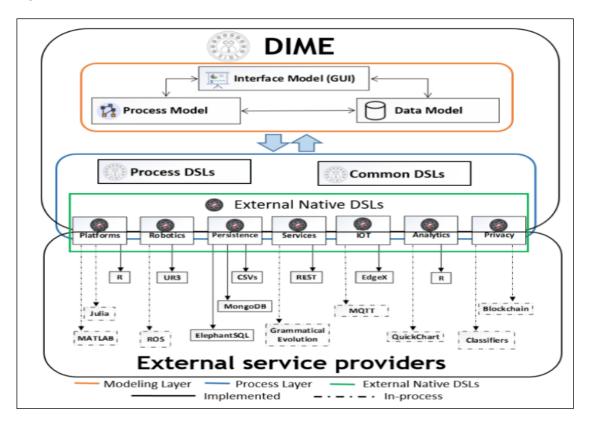

Figure 7: Architecture Overview of DIME and Custom DSLs (Margaria et al 2021)

Now that the overall high level architecture has been produced, the three canvases produced from the earlier paper can essentially be created and mirrored in a DSL approach for organisations to use. Instead of a workshop scenario, a DSL platform that conforms to such a framework outlined in Ryan and Margaria (2021) can be used to first prompt the user (organisation) to input the relevant details like the workshop did and then have the capabilities

to use the DSL to analyse the data along with more complex data that the organistaion might like to add in order to produce a circular approach to decision support and decision making. Outlining how it can be achieved is depicted in Figure eight with the various inputs and outputs showcased which can be utilised as guidance for the creation of a DSL to replace current workshop structures in place for sustainability. This figure examines two strands which are business logic and knowledge harvesting. As depicted, the model of canvas one along with the sustainability goals will be used as an input and as the process concludes the output will be the third canvas as per our workshop.
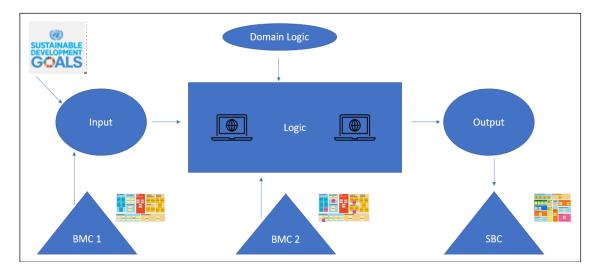

Figure 8: Logic and Understanding - Updated

4 Results and Discussion

The paper addresses the need to understand how the high level architecture will be structured to create a DSL platform for knowledge management. From analysis completed during the workshop, five important segments have been identified as critical for the successful adoption of such a process. The 5 segments as identified and discussed in the previous chapter have been portrayed to ensure the circular approach that organisations need to adopt will be utilised. These segments will essentially encompass vast amount of data which is critically important to consider. This combined with shaping how a workshop scenario could be depicted in a DSL setting were important goals delivered in this paper.

As we can see from these developments, there is a clear need for an effective description and formalization of data within a DSL platform if companies wish to utilise such a platform correctly. Just having the DSL and frameworks available to the company will not be enough as in order to actually make correct decisions it will be important for the data to be correctly collected, organised and then analysed. The data needs to be relational to each other to be understood correctly and most cases should produce ideally one or more ontologies at different granularities for companies to understand and analyse (Margaria and Ryan 2022). Generating

the data that is needed will depend on a multitude of factors but will specifically be aligned with the extended BMC of sustainability that was outlined. The approach that was undertaken is very much how organisations currently examine any business plan with a simple pen and paper approach. Now that an easy to follow framework has been created and the future of a DSL platform being examined, it will essentially aid in the adoption of a digitised approach for businesses to follow and reduce data loss as everything collected will be stored and analysed.

5 Conclusion and Outlook

In this paper we have examined various aspects of the high level architecture of a Domain specific Language platform for knowledge management with emphasis on risk and Sustainability. We introduced how Industry 4.0 is changing the current landscape of organisations and how if they wish to continue to stay profitable and successful, a change in the Status-quo currently effecting business planning and implementation needs to be addressed. We have showcased how the larger projects being developed under the Confirm banner and research group in general in terms of smart factories can be tailored in specific areas to our problem at hand in this research. We also showcased how a problem like sustainability and in a smaller way risk is proving to be a large scale issue for all organisations in any sector especially SME's from the case study and previous research outlined. We then outlined how a DSL platform could replace the current standard of consultants being asked to deliver workshops to companies who need expertise in this way while also showcasing how this can be delivered by utilising DIME and other relevant areas of research currently in operation in the larger group. This along with examining the importance of data within such a platform was also introduced. By using this qualitative approach and case study as the motivation of why a DSL is needed by companies in this way, we will be able to show why our research has changed the way companies will approach planning and modelling in the future and that it was research that needed to be completed in order to provide an alternative and better approach to sustainable frameworks that currently were available and provide companies with a bespoke DSL that they can integrate easily within their organisation for a circular approach to business modelling that produces long and successful organisations.

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