Conceptualising a Procurement 4.0 Model for a Truly Data Driven Procurement

A Digital Transformation Impacting the Procurement Economic, Social and Environmental Sustainability

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<td>AGV</td>
<td>Autonomous Guided Vehicle</td>
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<tr>
<td>BITKOM</td>
<td>Bundesverband Informationswirtschaft Telekommunikation Und Neue Medien Ev</td>
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<td></td>
<td>(Association for Information Technology, Telecommunications and New Media)</td>
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<td>B2B</td>
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<td>B2C</td>
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<td>C&amp;D</td>
<td>Construction and Demolition</td>
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<td>IoT</td>
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<td>MAAS</td>
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<td>Multi-Criteria Decision Making</td>
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<td>Manufacturing Service Ecosystem</td>
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<td>ROI</td>
<td>Return on Investment</td>
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<td>RPA</td>
<td>Robotic Process Automation</td>
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<td>SSP</td>
<td>Services Supporting the Product</td>
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<td>Services Supporting the Customer</td>
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<td>SAAS</td>
<td>Software-as-a service</td>
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<td>Small and Medium Size Enterprise</td>
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<td>Supplier monitoring activities</td>
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<td>Verband Deutscher Maschinen- und Anlagenbau (Mechanical Engineering Industry Association)</td>
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<td>ZVEI</td>
<td>Zentralverband Elektrotechnik- und Elektronikindustrie E.V. (Electrical and Electronic Manufacturers’ Association)</td>
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Sammanfattning:


Design / metod / tillvägagångssätt - Denna studie baseras på en systematisk litteraturstudie. En metod för att granska litteraturen och den aktuella forskningen för att föreslå konceptualisering av en upphandlings 4.0-modell.

Resultat - Resultaten från litteraturstudien bidrog till utvecklingen av en föreslagen upphandlings 4.0-modell baserad på Industry 4.0-teknologier, applikationer, matematiska algoritmer och automatisering av upphandlingsprocesser. Modellen bidrar till forskningsområdet genom att ta itu med klyftan i litteraturen om bristen på visualisering och konceptualisering av upphandling 4.0.

Originalitet / värde - Den nuvarande litteraturen diskuterar fördelarna, implementeringen och effekten av individer eller en grupp av industri 4.0-teknologier och applikationer på upphandling men saknar visualisering av transformationsprocessen för att kombinera teknologierna för att skapa en verklig datadriven upphandling. Denna forskning stöder skapandet av kunskap inom detta område.

Praktisk implementering / chefsimplikationer - Den föreslagna modellen kan stödja chefer och digitala konsulter att ha praktisk kunskap ur ett akademiskt perspektiv inom området upphandling 4.0. Kunskapen från litteraturen och den systematiska litteraturstudien används för att skapa kunskap om inköp 4.0 applikationer och analyser med beaktande av vikten av synlighet, transparens, optimering och automatisering av upphandlingsfunktionen och dess hållbarhet.
Abstract:

**Purpose** - Procurement is an integrated part of the supply chain and crucial for the success of manufacturing. Many organisations have already started the digitalisation of their manufacturing processes using Industry 4.0 technologies and consequently trying to understand how this would impact the procurement function. The research purpose is to conceptualize a procurement of 4.0 model for a truly data driven procurement. Two research questions were proposed to address the model from digital capabilities and sustainability preceptive.

**Design/Methodology/approach** - This study is based on a systematic literature review. A method of reviewing the literature and the current research for the propose of conceptualizing a procurement 4.0 model.

**Findings** - The findings from the literature review contributed to the development of a proposed procurement 4.0 model based on Industry 4.0 technologies, applications, mathematical algorithms and procurement processes automation. The model contributes to the research field by addressing the gap in the literature about the lack of visualization and conceptualization of procurement 4.0.

**Originality/Value** - The current literature discusses the advantages, implementation and impact of individual or a group of industry 4.0 technologies and applications on procurement but lacks visualization of the transformation process of combining the technologies to enable a truly data driven procurement. This research supports the creation of knowledge in this area.

**Practical Implementation /Managerial Implications** - The proposed model can support managers and digital consultants to have practical knowledge from an academic perspective in the area of procurement 4.0. The knowledge from the literature and the systematic literature review is used to create knowledge on procurement 4.0 applications and analytics taking in to consideration the importance of visibility, transparency, optimization and the automation of the procurement function and its sustainability.

**Keyword:** Procurement, Procurement 4.0, Applications, Visibility, Transparency, Data Analytics, Optimization, Automation, Sustainability.
1. **Introduction:**

Data driven procurement is a strategic thinking that is represented by the next generation procurement applications and analytics. It is represented by the development of the digital maturity of the traditional procurement function. A shift from a cost driven tactical buying to a data driven function that provide a strategic competitive advantage. Data driven procurement focus on the implementation of supply chain and procurement 4.0 solutions that enable visibility, transparency and agility of processes across the digital supply chain creating internal functional synergies and external collaboration with partners and suppliers. The aim is to achieve strong partnership, sustainable manufacturing, profitable business and satisfied customers.

Digital technologies such as Internet of things (IoT), data gathering and analysis using Big Data and business intelligence are driving manufacturing organisations to create new business models, forcing the shift from product-oriented offerings to digitally based service-oriented offerings. These service offerings are in the form of Services Supporting the Product (SSP) and Service Supporting the Customer (SSC) (Paiola, 2017). Digital servitisation resulting in new business models that impact organisations interdependencies, power and relationships. In particular, partners relationships and collaboration in the value ecosystem (Vendrell-Herrero et al., 2017).

The procurement function is one of the functions that are impacted by digital servitisation in which organizations are trying to create a new model and a sustainable value. Their focus is on creating a digital value chain management that reduce cost, control demand, improve processes, create synergies, develop collaborative partnerships and optimizes the supply chain.

The procurement function will face more internal and external challenges as market conditions change and the need for technology adaptation increases. So, the traditional procurement functions will need a digital transformation to tackle these challenges and risks. This can be done by redefining traditional procurement strategies, processes, best practices, the position in the value chain, the digital maturity level and develop a technology roadmap (Flood,2019).
Digitalisation comes with a complexity of understanding the digital transformation journey, the technology roadmap, business processes, implementation, change management and the training and development of employees skills. Organizations will have to vision the direction of the procurement function and how it will support the transformation of the business. Additionally, it is important to leverage on advanced analytics capabilities of internet of thing IoT, big data and artificial intelligence to enable a data driven “procurement 4.0”.

However, many organizations struggle with procurement digitalization. Therefore, it is necessary to enable the new generation of procurement functions and teams with full visibility, transparency, data analytics tools and technologies that will help manage cost reduction, supply base risk, contractual agreements, capture supplier’s innovation and activities and finally create sustainability. As a result, organizations can vision the implementation of automated sourcing tools, risk and compliance monitoring systems, intelligent supplier searching and selection tools, supplier real-time monitoring, tracking and spend analytics tools that can help achieve “procurement 4.0”.

There is a literature gap in the visualization of procurement 4.0 mentioned by Srai & Lorentz (2019) who highlighted the lack of visualization and a need to develop blockchains technologies in the context of procurement to support the development of the concept. Also, the same gap was mentioned recently in the literature by Tripathi & Gupta (2020) who highlighted that the literature discusses the implementation, impact and advantages of individual or a combination of industry 4.0 technologies on procurement process but lacks visualization of the transformation process of combining the technologies.

This research will use the systematic literature review for the purpose of conceptualizing a procurement 4.0 model to address the gap in the literature about the lack of the visualization. The findings from the literature review will contribute to the development of the model based on Industry 4.0 technologies, applications, mathematical algorithms and procurement processes automation. Therefore, the aim of this research is to answer the below two questions.

RQ1: What are the digital applications and analytics that will enable a digital Procurement 4.0?

RQ2: What is the impact of procurement 4.0 on economic, social and environmental sustainability dimensions?
2. Theoretical Background

2.1. Digital Servitisation

Servitisation offers manufacturing firms the opportunity to transform from traditional product offerings to leveraging on services as new business models. This means that they can become digital service-oriented firms. Industry 4.0 technologies such as industrial Internet of things (IoT) and big data analytics, are of high importance for analysing and understanding the enormous data that will direct long term strategies of firms. Firms can capitalise on their existing service offerings including predictive maintenance, warranty modelling, consumption control, energy savings, and customized use of the products to shift toward digitally based business models by introducing new concepts such as Software-As-A-Service (SaaS), Product-As-A-Service (PaaS), Machine-As-A-Service (MaaS). The developed new business models will introduce new revenues streams and billing systems based on equipment’s efficiency or actual rate of utilization. However, such transition and full adaptation in the business model is a challenge for many well-established firms (Paiola, 2017).

Digitalisation facilitates servitization in firms with new services, smart products, and platforms. Servitization as business models will create and capture new digital values. Manufacturing firms are using sensor-based technologies to enable cyber-physical systems (CPS), product-service systems (PSS) and smart solutions. Those manufactures will have to define the value system, the firm boundaries, and the impact of digitalization on business models in different positions within the value chain and the ecosystem. To gain value from digital servitisation firms must capitalize on three dimensions of digital offerings which are solution customization, solution pricing and solution digitalization. First, Solution customisation refers to the customisation of products software services to each individual customer requirements. Secondly, Solution pricing represent how organisation capture value through new revenue streams. Finally, and most important for the digital ecosystem is solution digitalisation which is an interplay between technology and the business model. Solution digitalisation is a development to older concepts such as remote product monitoring and diagnostics and smart connected products (Kohtamäki et al., 2019).

Traditional manufactures have business models that are focused on selling physical tangible products in traditional marketing segments through their supplier-buyer relationships. In many
occasions, these strategies are easy to copy by competition. So, manufactures will need to focus on the extended product through the establishment of “Manufacturing Service Ecosystem” (MSE) that will include the right service providers and suppliers. This will require radical change in the manufacturing business model. The business model is described as nine building blocks of value proposition, customer segments, channels, customer relationship, key resources, key activities, key relationships, cost structure and revenue streams. When manufacturers transform traditional products to extended product solutions offering, they will also transform their suppliers and the supply base into an ecosystem of network partners (Wiesner et al., 2014). Interestingly, Paiola (2017) highlights two factors that could affect the adaptation of digital servitisation, these are the position in the value chain and the type and nature of the distribution channel (i.e. the Sales Model) as per the matrix in figure 1. The next section will discuss the procurement and supply chain digital ecosystem.

Fig 1. The Business Model Change Matrix (Paiola, 2017)

2.2. The Procurement and Supply Chain Digital Ecosystems

Industry 4.0 focuses on the end-to-end digitisation of all physical assets and integrating it to the overall digital ecosystems and value chain. They offer more individualized experiences in a customer centric value chain through the transformation of digital culture and skills while focusing on data analytics and trust. Simultaneously, they manage the increase in third party data flows downstream with customers and upstream with suppliers. The increase in the data requires strong supply chain risk management and data integrity systems. Therefore, organisations are building dedicated functions focusing on industry 4.0 technology with clear
return of investment (ROI) (Reinhard et al., 2016). Each one of these dedicated functions across the supply chain will require a digital transformation and visionary level of digital maturity to move from a current as is state to a future to be state. Figure 2 shows the digital roadmaps for procurement by Flood (2019). The next section will discuss the digital maturity model and data analytics capabilities.

Fig 2. Tangible and progressive digital roadmaps (Flood, 2019)

2.3. The digital Maturity: Current state (As-is) and future state (To-be)

The procurement function is part of an overall supply chain and digital ecosystem, so it is important to look at the digital maturity of the whole digital ecosystem.

As the research propose a data driven procurement 4.0, the selected maturity model should reflect an understanding of industry 4.0 digital maturity, thus, the industrie 4.0 maturity index that focus on the management of digital transformation of functions and firms is used.

The principles of the application are based on three successive stages. The first stage, to identify the current capabilities (As-Is) state of the company and the functional digital maturity. Secondly, understanding the level of digital maturity that the organisation wishes to achieve based on the overall corporate digital transformation strategy and the desired capabilities
through gap analysis of the missing processes and technologies. Finally, creating an action plan and technology roadmap on how to achieve the required desired future (To-Be) state of digital maturity (Schuh et al., 2018).

The industry 4.0 development path consists of 5 stages, these are in order, computerisation, connectivity, visibility, transparency, predictive capacity and adaptability. Below are the levels in relation to the digital supply chain ecosystem and procurement 4.0.

- **Computerisation**: The basis of digitalisation, where each function has its isolated system. No digital connectivity with other function. Most organisations are advanced at this level where the focus is performing repetitive tasks. Such as repetitive buying tasks using excel sheets, e-mails and phones.

- **Connectivity**: Isolated information systems are connected with each other. The systems are interoperable and connected but not fully integrated. Internet protocols support the connectivity of the different systems. For example, a purchase ordering system connected and receiving orders from a production system.

- **Visibility**: Sensors are placed across the different functions within the digital supply chain, as the prices of sensors and microchips and network technologies drops. At this stage real time data can be collected throughout the supply and purchasing process. For example, a procure to pay (P2P) process connected with other processes across the organisations. This state of maturity known as the “digital shadow” of the company current processes.

- **Transparency**: At this stage organisations are trying to know the reason and cause for the current activities and use this understanding to produce knowledge. At this stage the interoperability across the systems is semantic, one where the data from across all functions create information and contextual meaning that help in the decision making process. At this stage the role of big data in procurement becomes crucial as the data increase and become more complex to manage by traditional organisation systems (e.g. traditional Enterprise resource planning (ERP)). At this stage there is a need for new data analytics capabilities and big data applications to be deployed alongside the organisation Enterprise Resource Planning systems. These technologies will carry out stochastics procurement analytics in order to reveal interactions, parameters and dependencies across the digital supply chain for complex decision making such as
purchasing requirements over period of time based on real-data from consumer usage. This level of transparency is a requirement for the next stage of predictive capacity.

- **Predictive Capacity:** At this stage the organisations will simulate different scenarios, predict the likelihood of occurrence and predict the most suitable future actions. This gives the organisation the opportunity to create strategies and action to tackle these challenges within a timeframe which will help to manage unpredictable sourcing and procurement risks with external suppliers driven by consumers demand, manufacturing requirements and challenges downstream. These actions are not yet fully automated.

- **Adaptability:** Predictive capacity is a requirement for adaptability where all operations, predictions and many decisions are automated. The level of automation will depend on the repetition nature in the tasks or processes, the return on investment, and the risk evaluation of extending automation approvals and acknowledgments upstream to suppliers and downstream to customers in which a risk evaluation is required (Schuh et al., 2018).

### 2.4. Data Analytics in the context big data, business and artificial intelligence

According to Pause & Blum (2019) the term analytics in relation to business intelligence “is understood as a scientific process of mathematical-logical transformation of data to improve decision making. Depending on the maturity level of analytical skills, four stages of data analytics can be defined: descriptive, diagnostic, predictive and prescriptive analytics”

- **Descriptive Analytics:** aim to ask the question of “what happened?” so, the aim is to analyze large amount of data to understand what has happened in the past.

- **Diagnostic Analytics:** aims to answer the question “Why did it happen?”, by analyzing the interactions.
• **Predictive analytics**: aim to ask the question “What will happen?”, trying to predict future behavior by using methods of pattern recognition and the use of statistics knowledge. This support proactive optimization.

• **Prescriptive analytics**: also support proactive optimization being the last stage aims to answer the question “What should be done?” by using algorithms and simulating different possible scenarios suggesting measures and, corrective actions and implement these measures automatically with no human intervention. This supports the achievement of full automation through a cyber-physical system (CPS) or a digital twin (Pause & Blum, 2019).

Figure 3 describe these analytics in relation to the level of human interaction, decision making processes and the actions and measures.

![Fig 3. Data analytics capabilities (Pause & Blum, 2019).](image)
2.5. Reference Architectural Model for Industry 4.0 (RAMI 4.0)

Servitisation bring great opportunity for redesigning existing business value chain and business processes and create digital value using industry 4.0 technologies across manufacturing and the supply chain. This includes Procurement 4.0. The challenges of procurement processes design and barriers of integration and automation has been highlighted in the literature. There is a need for a common understanding of the integration of data through the integrated information platforms used by buyers and suppliers. (Akyuz and Rehan, 2009). So, the design of standard data transmission protocol to transmit information and communicate through the integrated information platforms should be agreed between the stakeholders (Huddad et al., 2016; Zolnowski et al., 2016). Additionally, the same common understanding should be applied between the buying and supplying organisations and across the industry throughout the supply chain.

The reference architecture model Industry 4.0 (RAMI 4.0) is a model that has been developed by industrial organisations, BITKOM, VDMA and ZVEI in Germany, with the aim to secure future coordination, initiatives and common understanding across the industry in relation to industry 4.0. The model also is useful as a tool for the purpose of architecting the system. The rest of this section will discuss the use of RAMI 4.0 tool box for modelling industrial systems and their interactions and map them as in figure 4 in three-dimensional cube.

![Fig 4. RAMI 4.0 Reference Architectural Model Industry 4.0](https://ec.europa.eu)
2.5.1. Interoperability Layers

On the left side of the toolbox, there are the six interoperability layers. These are as below:

- **The business layer:** It supports business model servitization and represents the business information that will be exchanged to support industrial processes. These can be market and economic information, regulations and policies. In addition, information about the company’s products and portfolios such as product service systems business capabilities and processes. This layer is key in business decision making such as new market models and new business models.

- **The function Layer:** From an architectural point of view, it describes the functions, their interactions and the services performed.

- **The information Layer:** Describes the type of information that is being exchanged between functions, service and components. This layer allows for interoperable exchange of information through the communication tools in the communication layer.

- **The communication Layer:** This layer describes the ways, protocols and mean of communication that support the interoperable exchange of information across the components.

- **The integration Layer:** The layer helps to create events by providing all physical assets to the other layers. These events also called administration shells. These administration shells act as foundation to provide information for further processing. This layer shows the context of each asset through usage and integration of network components (switches, routers, terminals) or passive ones (QR codes and barcodes).

- **The asset layer:** Conceptual smart grid that contains the physical distribution of all the participating components such as physical components, applications, ideas, system actors and humans (Binder, 2017)
2.5.2. RAMI 4.0 plane, life cycle, value stream and administration shell

Each layer mentioned earlier is depicted by the utilisation of industry 4.0 plane, which is an application based on a cyber physical-system (CPS) that distinguish between information management viewpoints and electrical processes. This allows the representation on the areas in which actions and interaction between single assets take place as well as the classification of those from a management point of view.

RAMI 4.0 combine all the IT components and elements in a layer and life cycle model, simplify processes in to packages including cybersecurity and data privacy. The pyramid in left side of figure 5 shows the organisations or factories that are based on functions which are hardware-based structure and with hierarchical communication. These are not connected with the external world. They are also not connected with the products manufactured. The figure also represents RAMI 4.0 hierarchy levels.

On the other hand, the image on the right side of figure 5 depicts a smart grid of industry 4.0 that are connected with the connected world outside the organisation or the smart factory. This grid highlight flexibility of systems and operations where functions are network distributed. Participants and communications are distributed across all levels (non-hierarchical). Additionally, the products offered are smart and connected products. The smart products are a key to a new business model of servitisaion.

Fig 5. From hierarchical to connected using RAMI 4.0 (https://ec.europa.eu)
Finally, the administration shell (figure 6) is a reflection of a virtual image of an object. It is the database that has the information of an object of a manufacturing system, tool or product. It is the point of integration between the physical world or asset and the cyber or digital world and has the standardised network communication interface. The purpose is to exchange data among industrial assets and work to facilitate many to many communication and orchestration between physical assets (Binder, 2017).

Fig 6. The Administration Shell of the cyber or digital world (https://ec.europa.eu)
3. **Methodology:**

This section explains the general difference between the traditional and systematic literature review, then it will explain the systematic literature review that has been used in this research.

### 3.1. Traditional Literature Review versus Systematic Literature Review

A literature review is considered by itself a research method. A thesis methodology has the aim of improving the quality of the literature review, raise awareness of the systematic review protocol. A literature review is a method involving the secondary analysis of knowledge. It is an opportunity to explore the abstract concepts of explicit and tacit knowledge. Taking in to consideration the importance of originality and contributing to the building and creation of new knowledge (Jesson et al., 2011).

It is important to understand the difference between “Traditional Literature Review” versus “Systematic Literature Review”. Traditional literature review is a written appraisal of the knowledge that already exist, which is already known. It has no specific methodology (Jesson et al., 2011).

On the other hand, systematic literature review has been defined as “a method of making sense of large bodies of information and a means to contributing to the answers to questions about what works and what does not” (Petticrew & Roberts, 2006). Such review based on a systematic review method can be described in six protocol or essential stages as below.

1. Defining a research question
2. Designing a plan
3. Searching for journal articles in the literature
4. Use inclusion and exclusion criteria when selecting the journal articles
5. Apply a procedure of quality assessment
6. Synthesis

Systematic means that the method should follow an order. It should not be random but follow a methodological approach. Following a systematic approach for literature review supports the search for knowledge, applying the knowledge and creating further development knowledge.
The methodology will still consider the identifying of gaps and highlighting future research opportunities (Jesson et al., 2011).

The methodology includes identifying and selection of keywords to search journal articles in databases such as Scopus that are peer reviewed. In many cases these articles have an established perspectives and paradigms. So, creating knowledge that produce new paradigm or fresh movement is considered challenging.

The keywords used in searching the database, known also as “natural language” are selected based on the understanding of the field of sturdy or by reviewing other keywords used in other articles. Additionally, checking that the selected keywords match the words in the databases indexes. Below are three tips that are common:

- Select keywords from the research statement or question.
- Identity similar or synonymous terms using a reference dictionary or thesaurus.
- Identify keywords and subject terms from the selected database.

Secondly, constructing the key search statement with Boolean operators AND / OR / NOT

- “AND” is used to find article that contain a number of keywords. It will also support to narrow down the articles and be more specific. It is also used to search for words within different fields.

- “OR” is used for selecting an article that contain a specific word or the other word.

- “NOT” is used to look for one keyword or term but not the other. It is used to exclude irrelevant results to narrow down the research

A combination of the above can be used along with wildcard such as “*” that can be use for alternative ending. For example, when searching for “sustain*” the search will generate results for sustain, sustainability and sustainable (Jesson et al., 2011).
Finally, it is important to keep record of the searching criteria, activities and results. Including the database or sources, the date of search, the keywords, scope and references. The references that are relevant to the topic should be reviewed considering inclusion and exclusion criteria such as geography, time span, research methodology, language or the selection of articles that has been published during a specific number of years. It is important to select one or more database that have extensive source of material from academic or the professional sector in the form of research, journals, company information, official legal or government information. The next section will focus on the systematic literature review methodology used for this research.

3.2. The Thesis research Method: A systematic Literature Review.

To generate knowledge on procurement 4.0 digital applications and analytics and knowledge on how a data driven procurement 4.0 will drive sustainability, the research approach will focus on the development of the existing knowledge. As a result, a systematic literature review process of reviewing the academic literature as discussed earlier by Jesson et al., (2011) was conducted to map the state-of-the-art knowledge. The methodology is based on clarifying the purpose of the research, formulating two questions, identify keywords, choosing a peer reviewed database, then moving to a rigorous identification of relevant research papers, interpreting, and finally organising the content.

3.2.1. Identification of relevant research

A systematic selection process was conducted (see Table 1 for research protocol). A keyword search was conducted in Scopus (for title, abstracts and keywords). Three groups of keywords were defined based on an explorative search of some key articles. The first one indicating procurement. The second covering digitalization. The last one focusing on data analytics and sustainability (see Table 1 Search Query or Annex). One keyword from each of the group was required for the article to appear in the search results (the boolean operators “AND” was used for each group and “OR” within these groups of words). The initial result of the search in Scopus database, were 501 papers, varies between journal articles, conference papers and other documents.

After the keywords search, it was important to define initial inclusion and exclusion criteria. The focus was to include all the journal articles that were in English and were published
between the years 2016 to 2021 as early discussion on procurement 4.0 is around 2016. The criteria were set to journal articles only resulting in a final 151 journal articles.

Finally, the 151 selected articles were reviewed in a number of review rounds including quality assessment by applying criteria of inclusion and exclusion. Articles were to be included if:

- Articles focusing on procurement 4.0
- Articles provided findings connected to data, technologies and applications of procurement digitalization using Industry 4.0 such as IoT, Big Data, The Cloud, Blockchains, Robotics process automation, using algorithm, data analytics and statistical analysis.
- Articles discuss the importance of visibility, transparency and automation in procurement.
- Articles focus on one or more sustainability dimensions including economic, environmental and social aspects such as reducing environmental footprint, waste management, corporate social responsibility (CSR), supplier monitoring activities (SMA), traceability, shared economy and circular economy.
- Else, the articles were excluded.

The decision to exclude and include the articles were made based on reading abstracts, title and keywords of the articles. Some excluding criteria included as below:

- Articles that had not technological background or limited discussion on e-procurement without mentioning industry 4.0.
- Articles that focused on traditional procurement processes
- Articles that have no sustainability focus.

This phase ended up in a sample of 50 articles. In the second phase, the full articles were read, the same inclusion/exclusion criteria were applied. If an article did not meet the criteria a decision was made to exclude it. Initial results were 26 articles, then were reduced by 2 more articles to 24. The result was the selection of 24 articles chosen as the final reference for this research.
Table 1. Research Protocol

<table>
<thead>
<tr>
<th>Research protocol</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Research database</td>
<td>Scopus Database</td>
</tr>
<tr>
<td>Publication type</td>
<td>Journals indexed by Scopus</td>
</tr>
<tr>
<td>Language</td>
<td>Articles in English language are considered</td>
</tr>
<tr>
<td>Date range</td>
<td>The range period for consideration was 2016 until 2021</td>
</tr>
<tr>
<td>Search fields</td>
<td>Titles, abstract, and keywords</td>
</tr>
<tr>
<td>Search query: applied in Article Titles, Abstracts, and Keywords in Scopus.</td>
<td>(TITLE-ABS-KEY (procurement 4.0) OR TITLE-ABS-KEY (procurement) OR TITLE-ABS-KEY (purchasing) OR TITLE-ABS-KEY (sourcing) AND TITLE-ABS-KEY (digital*) OR TITLE-ABS-KEY (visibility) OR TITLE-ABS-KEY (transparency) AND TITLE-ABS-KEY (big AND data) OR TITLE-ABS-KEY (data AND analytics) OR TITLE-ABS-KEY (data AND driven) OR TITLE-ABS-KEY (data-driven) OR TITLE-ABS-KEY (intelligence) OR TITLE-ABS-KEY (automation) OR TITLE-ABS-KEY (application) OR TITLE-ABS-KEY (sustain*) ) AND (LIMIT-TO (SRCTYPE , &quot;j&quot;) ) AND (LIMIT-TO (DOCTYPE , &quot;ar&quot;) ) AND (LIMIT-TO (LANGUAGE , &quot;English&quot;) ) AND (LIMIT-TO (PUBYEAR , 2021) ) OR LIMIT-TO (PUBYEAR , 2020) ) OR LIMIT-TO (PUBYEAR , 2019) ) OR LIMIT-TO (PUBYEAR , 2018) ) OR LIMIT-TO (PUBYEAR , 2017) ) OR LIMIT-TO (PUBYEAR , 2016 )</td>
</tr>
<tr>
<td>Criteria for inclusion</td>
<td>Articles that presented findings on data sources or procurement applications, technology and analytics in procurement and articles on procurement sustainability</td>
</tr>
<tr>
<td>Criteria for exclusion</td>
<td>Articles that did not include applications, technology or analytics of procurement or procurement sustainability as a main topic.</td>
</tr>
</tbody>
</table>

The above Table 1 and figure 7 below presents the research protocol for the SLR. The first step of the SLR was done by reading the title, abstract, introduction and conclusion of 151 articles. After this process, 50 journal articles were selected which is relevant to the topic. Then after conducting a full reading of the articles in order to assess the quality of each article, 26 articles were selected. After that a quality assessment was conducted, there were 24 articles chosen as the final reference for this research.
3.2.2. Organizing and Interpreting

For data extraction a systematic coding process was used in a separate excel sheet. A coding system was developed based on exploring the literature. An initial coding round was conducted to test the process and codes, later some adjustments were made. The codes include the citation information such as publication year, journal, authors, title. Additionally, method, data and terms used to include procurement 4.0 technologies and digital applications impacting procurement transparency, visibility, automation. Furthermore, economic, social and environmental substantiality dimensions were coded under the general sustainability theme. Additional codes were allowed to emerge.
3.2.3. Synthetization and Forming

The results of the systematic literature review coding were summarized in chronological order as per table 4. There was a need to review the articles a couple of times, to check that the coding is correct. The journal articles were observed on areas of digital applications and analytics including industry 4.0 technologies and data analytics that will increase visibility and transparency in procurement, optimize the decision-making process and automate procurement processes. This was important to address research question and to conceptualize the procurement 4.0 model. The second important coding was in relation to the impact of procurement 4.0 on sustainability dimension. It included the positive and possible negative impact on economic, social and environmental sustainability dimensions.

As procurement is an integrated part of the supply chain, logistics and manufacturing. The coding considered the rich knowledge on procurement processes and governance such as supplier selection, procurement contracts, bidding and tendering process, buyers suppliers’ relationships, the management of the supply base and the supply network, the supply risk management, supplier monitoring activities, supply chain traceability, corporate social responsibility, ethics in relation to conflict minerals, employment practices and environmental footprints. The discussion was classified and synthesized based on the findings from the literature to cover end to end supply chain network and procurement processes including upstream supply chain, production, and downstream supply chain. This help to discuss the use of technologies, applications and analytics to address the challenges of the procurement function. The results of the literature review organizing, interpreting and coding are presented in the next literature review chapter.
4. Literature Review

This section will discuss the findings of the systematic literature review. It will start by discussing the general analysis of the selected papers including the number of papers per year, research field, sector and industry analysis. Then it will discuss the research purpose and methods of the selected papers. Finally, the research question (RQ1) and research question (RQ2) will be answered based on the findings from the systematic literature review.

4.1. Number of Papers Per Year

The 24 papers spread over a period of 6 years from 2016 until 2021. As the area of Procurement 4.0 is recent, most of the papers that addressed both procurement digitalization and sustainability were recent papers including 8 papers in 2021, 8 papers in 2020, 5 papers in 2019, 2 papers in 2018 and finally a paper in 2016 with focus on sustainability as per the graph in figure 8.

![Number of publications per year](image)

Fig 8. Number of publications between 2016 until 2021 (n=24)

4.2. Analysis of Research field, sector and Industry.

The selected research papers had diverse knowledge of procurement. The procurement environmental impact being the most discussed topic covering areas such as combining environmental product declarations (EPDs) and product category roles (PCR) to improve the
decision making process and increase visibility of manufacturing footprints in public procurement (Rangelov et al., 2021), the use of data from Life Cycle Assessment (LCA) application and environmental product declarations (EPDs) by applying statistical analysis to use it as a benchmarking tool (Welling & Ryding, 2021). Additionally, the construction and demolition industries are very conscious about their environmental impact and waste management (Bao et al., 2019). The industry uses blockchains in construction waste management system to measure, treat waste and for traceability (Pellegrini et al., 2020). Finally, the importance of procurement 4.0 is seen as a key enabler for open and closed loops supply chain and the establishment of a circular economy (Bag et al., 2020).

Another research filed is the procurement optimization through the use of mathematical and statistical analysis including the use of mathematical tools for improving purchasing data quality to identity purchasing risks (Shabani-Naeeni & Ghasemy Yaghin, 2021), the use of Multi-Criteria Decision Making (MC DM) to improve the selection criteria of suppliers in complex purchasing and supply chain environments to support sustainable optimized decision-making process in procurement (Dotoli et al, 2020). Furthermore, the use of Supply Network Link Predictor (SNLP) method to study interdependencies between suppliers within the supply network which impact the buyers’ suppliers’ relationships (Brintrup et al., 2018) and finally, the use of predictive analytics to predict the final time of completion of work within the supply chain network (Liu et al., 2020).

Procurement process automation is another research filed and is discussed through the use of robotic process automation (RPA) (Viale & Zouari, 2020). In addition, the use of automated purchasing systems with artificial intelligence (Oh, 2019), the use of downstream intelligent marketing analysis platforms for the customization of communications and product or service offerings by the suppliers in a Business-to-Business environment (Suzuki et al., 2019).

Social sustainability was presented as social responsibility in the area of procurement. Corporate social responsibility (CSR) was discussed in the context of supplier monitoring activities and reporting (Duan et al., 2021), its impact on consumer’s buying choices (Egels-Zandén & Hansson, 2016). Finally, the importance of procurement communication (Koponen & Rytsy, 2020) and procurement digital capabilities (Srai & Lorentz, 2019) were presented as research fields in the literature.
The selected papers were classified in categories based on the research paper filed focus. The highest were papers with focus on environmental impact, followed by mathematical and statistical analysis. Then equally, categories of procurement automation, procurement corporate social responsibility and papers with focus on blockchain technology. The last categories general procurement applications, technologies and capabilities that has the focus on using one or more industry 4.0 technologies in procurement. The graph (Figure 9) shows the different research fields.

![Analysis of Research Field](image)

**Fig 9. Analysis of Research Field (n=24)**

In relation to sectors analysis, the private sector was highest, then followed by the public procurement sector. Some papers presented both private and public sectors. This indicates the importance of the area of procurement digitalization for both sectors. Additionally, universities and academic research were also presented as per the graph in figure 10.
Finally, the education sector represents research papers from universities (non-industrial). Multi-industries have been presented in many papers including automotive, pharmaceutical, consultancy, power, engines. However, the concentration of industries were the construction and the meat and livestock where sustainability was discussed extensively. Variety of other industries were presented such as e-commerce, electronics, mining, retail, textile and small and medium size enterprises as per the graph in figure 11.
4.3. Analysis of research purpose

The research papers have a diverse research purposes and perspectives on procurement digitalization and sustainability dimensions.

The researchers aimed to study areas such as the use of Industry 4.0 technology in supply chain and procurement (Fatorachian et al, 2021), procurement 4.0 to facilitate circularity (Bao et al., 2019) or shared circular economy (Bag et al., 2020). In particular, many researchers worked on the development of blockchain technology and its use in procurement for the development of smart contracts (Gunasekara et al., 2021), including integrating blockchain vertically and horizontally for waste management strategies and information management in the construction industry (Pellegrini et al., 2020) and the use of blockchain for traceability and its positive impact on corporate social responsibility (Sander et al., 2018).

Furthermore, environmental sustainability was discussed including the use of environmental product declarations (EPDs) combined with product category roles (PCR) to improve environmental sustainability in green public procurement (GPP) (Rangelov et al., 2021) and the use of Life Cycle Assessment (LCA) analysis combined with PDE environmental product declarations (EPDs) as benchmarking tools (Welling & Ryding, 2021). Finally, the analyzing available market data for wall-to-wall mapping of supply chain network to manage the supply base and quantify purchase risk (Zu Ermgassen et al., 2020) as well as the tracking and tracing of critical material and minerals in the electronics and mining industry (Young et al., 2019).

From a procurement optimization perspective, the use of data quality and algorithm to predict risk in purchasing (Shabani-Naeeni & Ghasemy Yaghin, 2021), the use of Multi-Criteria Decision Making (MCDM) to improve the selection criteria and decision-making process in procurement (Dotoli et al, 2020), the use of the Supply Network Link Predictor (SNLP) method to study interdependencies between suppliers within the supply network and its impact on the relationships (Brintrup et al., 2018) the use of predictive analytics to predict the final time of completion of work in the supply network (Liu et al., 2020).

Procurement automation is researched through the use of robotic process automation (RPA) (Viale & Zouari, 2020), the use of automated purchasing system with artificial intelligence
and the use of a cloud integrated ERP system for purchasing automation (Keitemoge & Narh, 2020), the use of digital e-receipts applications (Gavrila Gavrila & de Lucas Ancillo, 2021) and intelligent marketing platforms in business to business relationships (Suzuki et al., 2019) for the communication and customization of customers offerings.

Finally, the area of procurement corporate social responsibility was discussed including supplier monitoring activities and reporting (Duan et al., 2021), its impact on consumer’s buying choices (Toussaint et al., 2021; Egels-Zandén & Hansson, 2016), procurement communication (Koponen & Rytsy, 2020) and procurement digitalization capabilities (Srai & Lorentz, 2019) were highlighted in the research purpose.

4.4. Methods

There are various methods used in the literature. The main methods were mathematical and statistical analysis, case studies, designed methodologies, mixed models, literature review and surveys. Other methods include role play experiment and focused group as per the graph in figure 12. One of the papers was based on knowledge shared by consultants without specific methodology.

![Methods Analysis](image_url)
4.5. RQ1: What are the digital applications and analytics that will enable a digital Procurement 4.0?

Traditional procurement processes are manual. Data and information in the function are paper based or stored in standard databases. The system between buyers and suppliers in Business-to-Business relationships are connected through electronic data interchange that connect the buyers with the supplier’s enterprise resource planning systems. The data and information exchange reflects the situation at the time of the transaction. There is no visibility, real time data transparency or information exchange, difficult to optimize and automate procurement processes across the supply chain and manufacturing. The challenge to transform traditional procurement to procurement 4.0 require an understanding of the procurement digital maturity and the digital capabilities, applications and analytics in the area. As a result, the applications and analytics will be discussed from a perspective of procurement visibility, transparency, optimization and automation.

Sensors enabled by Internet of things IoT and real time data collection enables the comprehensive monitoring of the end-to-end procurement, supply chain and manufacturing. Data collected from the environment are important in the process of the procurement function visibility and its digital transformation. Procurement visibility is an important enabler in the procurement digital transformation and data are an important element of the digitalization process. Data visibility concerns the quality and accuracy of data. An important concept is data veracity through which data quality provides data integrity (Shabani-Naeeni & Ghasem Yaghin, 2021). Industry 4.0 based Technologies such as Internet of things (IoT) enhances decision making through real-time data collection across procurement, the end-to-end supply chain ecosystem and through use of sensors embedded in consumer products. This creates advance visibility of operations (Fatorachian & Kazemi, 2021; Srai & Lorentz, 2019).

Another important enabler of procurement visibility is data security which is crucial for the digital development of the procurement function. Blockchain technologies are going to transform the documentation process (Gunasekara et al., 2021). Documents such as environmental product declarations (EPDs) (Rangelov et al., 2021; Welling & Ryding, 2021), and buyers and suppliers’ contracts will become smart, secure and managed through blockchains. Advanced blockchain based digitalized tools will improve procurement processes through data security, improving poor integration and communication in business-to-business relationships (Gunasekara et al., 2021).
Additionally, firms can obtain data from downstream supply chain activities. Information and knowledge about retailers, customers and end users are an important source of knowledge that will add value to the procurement decision making. Information in the form of historical data such as invoices, product usage or data from social media analytics are of a high value. The downstream data collection will create end to end visibility across the supply chain (Gavrila Gavrila & de Lucas Ancillo, 2021).

**Data visibility in procurement** is important for information exchange and transparency across the supply chain ecosystem. Visibility is important to enable the contextualization of information (Duan et al., 2021), the development of procurement automation (Viale & Zouari, 2020), the coordination with suppliers (Koponen & Rytsy, 2020) and increasing transparency downstream with consumers (Gavrila Gavrila & de Lucas Ancillo, 2021).

**The procurement function applications**, platforms and software connected across the end-to-end supply chain and manufacturing enables the control of procurement and information exchange between the different parties. Such holistic Integration and information sharing, integrates the procurement function with the supply base, suppliers and manufacturing to support the collaboration and cooperation leading to procurement transparency (Fatorachian & Kazemi, 2021). In addition, the same is applied downstream with consumers as online information technology platforms will continuously collect behavioral information about the buying decision making process. A Transparency through understanding cross-selling and up-selling patterns so that the sellers can create new engaging campaigns that meet customer interest and demands (Gavrila Gavrila & de Lucas Ancillo, 2021).

**Blockchains based applications** will increase transparency in procurement documentation practices by creating secured and transparent transactions. Blockchain work as a digital consensus mechanism that will enable smart contracts. Other features of blockchains such as data encryption mechanism, hashing mechanism and hyperledger can be used to tackle transparency and security issue (Gunasekara et al., 2021). The combination of a smart digital environmental product declarations (EPDs) and Life cycle assessment (LCA) applications, increase transparency and better decision-making process. This can be achieved through the benchmarking, visualization and communication of the environmental results (Welling & Ryding, 2021).
The electronics, commodity and mining industry are facing major issues in relation to the traceability of critical minerals within the supply network (Young et al., 2019). As a result, Blockchain will facilitates the creation of **applications and platforms for traceability**. For example, the meat and livestock industry have used blockchains for meat tractability by combining them with meat DNA coding for the identification, accuracy and higher information security and exchange across procurement and supply chain. (Sander et al., 2018). Furthermore, blockchain will support the availability of accurate information about the industry activities from early bid throughout the entire lifecycle of products and projects and at the end-of-life cycle. A blockchain vertical integration would allow the creation of a combined platform for the digitalization of the entire procurement and supply chain end to end process, securing the identity of participants, the immutability of the documents and the possibility to develop smart contracts. On the other hand, A horizontal integration of blockchain would allow for traceability of the entire life cycle of the product used during projects and support an efficient development of a green procurement practices through to the integration of tractability software that track and trace the product from raw material to the end of its life (Pellegrini et al., 2020). Such traceability applications combined with current market available data will offer wall to wall mapping of the procurement supply base and suppliers’ activities which will improve procurement transparency and the decision-making process (Zu Ermgassen et al., 2020). As a result, Supplier monitoring activities (SMA) and disclosure applications are central to achieving supply chain transparency and corporate social responsibility. This can be used as a consumer corporate tool to influence purchase behavior (Toussaint et al., 2021; Egels-Zandén & Hansson, 2016).

**Cloud-based solutions for the applications of communication** between buyers and suppliers (Suzuki et al., 2019), in business to business (B2B) e-commerce (Koponen & Rytsy, 2020) or in communication downstream with consumers and customers such as **cloud-based e-receipts applications** in retail (Gavrila Gavrila & de Lucas Ancillo, 2021) are important to facilitate procurement decisions. In business to business, it will help to create a one-to-one communication leading to transparent communication between buyers and suppliers (Suzuki et al., 2019). Enabling the interaction between buyers and suppliers (B2B) to be more relational, interactive and continuous through social presence that vary depending on the stage of the buyer supplier relationship. Enhancing the online interaction experience in form of customizable online chat, based on the buyer requirements, historical interaction and
classification of the type of buyer (i.e., new prospect or current customer) (Koponen & Rytsy, 2020).

**Cloud based applications** are critical for the success of the *electronic purchasing system* that will enable transparency, visibility and accessibility of information exchange in procurement processes. For example, sales data provides traceability to each and every purchase transaction executed but it is the most beneficial when correlated to the customers. A company can compile statistics and extract patterns from invoices, and provide personalized offerings based on consumers’ habits and preferences. New production, consumption and payment services using digital servitisation such as software-as-a-service is facilitated by the use of cloud-based E-receipt solutions. E-Receipt platform helps companies grow their business by transforming the traditional offerings into a digitalized hybrid solution (Gavrila Gavrila & de Lucas Ancillo, 2021). Finally, on-site enterprise resource planning systems (ERPs) are being replaced by the **cloud-based enterprise resource planning systems (ERPs)**, because these systems utilize up-to-date and available cutting-edge technology platforms to reach a vast number of users and businesses in a global supply chain network (Keitemoge & Narh, 2020). Synchronizing the information flow with the physical flow of goods to support a greater procurement and supply chain integration, transparency, information exchange (Suzuki et al., 2019).

The increase of visibility and transparency of procurement will enable the use of algorithms that will **optimize the applications** of procurement operations and processes by enhancing the procurement function performance and allow for predictive diagnostics, services and decisions in real time. **Multi-Criteria Decision Making (MCDM) techniques** are mathematical tools for the applications of Supplier Selection Problem (SSP). The techniques include the Analytic Hierarchy Process (AHP), the Preference Ranking Organization Method for Enrichment of Evaluations (PROMETHEE), the Multi Attribute Utility Theory (MAUT), and the Data Envelopment Analysis (DEA). Multi-Criteria Decision Making (MCDM) techniques help procurement decision makers in the evaluation and ranking the different possible alternatives of suppliers over multiple conflicting criteria in highly complex environments (Dotoli et al., 2020).

The supplier selection problem (SSP) is not the only issue in procurement optimization. Manufactures often lack visibility of the procurement and supply chain interdependencies
between the suppliers within their supply network. However, the knowledge of these interdependencies within the supply network is useful to plan for the potential operational supply chain risk and disruption. The Supply Network Link Predictor (SNLP) employ classification algorithms from the field of machine learning such as Naïve Bayes and Logistic Regression to predict whether the selected features can help predict interdependencies between two or more suppliers (Brintrup et al., 2018).

Original equipment manufacturers (OEMs) have complex supply base and large number of suppliers. OEMs source parts from hundreds of distributed suppliers globally, including small and medium size enterprises (SMEs). SMEs also obtain parts from a complex supply network. As a result, two supervised machine learning regression models, namely, random forest and quantile regression forest (QRF) can be used to learn from historical transactional data and predict models for the completion time of work orders (i.e. purchase orders and sales orders). These models increase the overall level of trust within supply chain networks (Liu et al., 2020).

Procurement optimization include the use of statistical analysis tools for calculating and visualizing environmental indicators for the purpose of benchmarking and interpretation of the procurement and supply base environmental activities and performance (Welling & Ryding, 2021). The main objective of Information modelling and mathematical and statistical analysis is to support procurement decision making by ensuring the accuracy and availability of information for procurement professionals. An integrated design system that allows all participants such as designers, contractors and suppliers to operate in coordination and collaboration by managing all information on the same platforms. Information modeling contributes directly to the implementation of open and closed loops supply china and the shared circular economy (CE) that will impact the procurement function key performance indicators and financial performance (Bag et al., 2020; Pellegrini et al., 2020; Bao et al., 2019).

Procurement optimization allows for autonomous, self-coordination and automation of procurement processes both internally with manufacturing and externally with suppliers. This will allow for autonomous procurement, digital servitisation and customized service offerings. The traditional procurement is changing to adapt to new paradigm of robotization. Robotic Process Automation (RPA) is "a preconfigured software instance that uses business rules and predefined activity choreography to complete the autonomous execution of a combination of processes, activities, transactions, and tasks in one or more unrelated software systems to
deliver a result or service with human exception management” (IEEE Corporate Advisory Group 2017, cited by Viale & Zouari, 2020). To established procurement automation, there is a need for clear, well-defined and immutable processes (Viale & Zouari, 2020).

Additionally, Procurement automation can be achieved through the use of **cloud web-based automated purchasing and ordering system** to share product data such as production planning information, ordering information, delivery information, quality determination information, and inventory status in real time among suppliers and business partners in the supply chain. Such a model stresses the important of autonomy, the interconnected automation of business processes based on artificial intelligence (AI) and the treatment of big data collected through the internet of things (IoT) in real and the utilization of generated information to support automated procurement decision making with less human intervention. Such Synchronizing of information flow with the physical flow will establish a greater procurement and supply chain integration. This integration is key to establish a cyber physical system (CPS) that connect the procurement physical world with the cyber world (Oh, 2019).

The same level of automation is required in downstream supply chain to support accurate procurement decisions based on consumer requirements and consumption. For example, the use of **big data marketing analysis platforms enabled by artificial intelligence (AI)** to determine market demand. Data from management platforms (i.e., e-mail and response data, external site behavior data, own site behavior data), customer relationship management (CRM) data (i.e., contracts, signer data, purchase history data, address data, query data), IoT digital contact points across warehouses, the distribution supply chain and in retail will establish the intelligence required to automate downstream processes to support procurement automation. It will be possible to execute more effective digital marketing by analyzing clients’ behavior that leads to purchases of products or services and the establishment of smart contracts (Suzuki et al., 2019). Table 2 summaries the digital applications and analytics that will support the establishment of procurement 4.0.
Table 2. Procurement 4.0 Applications and analytics

<table>
<thead>
<tr>
<th>Procurement 4.0 applications, optimization and automation using Industry 4.0 and Data Analytics</th>
</tr>
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<tbody>
<tr>
<td>Upstream and downstream real time data collection and monitoring applications by using IoT, sensors and big data analytics (Fatorachian &amp; Kazemi, 2021; Gavrila Gavrila &amp; de Lucas Ancillo, 2021; Shabuni-Naeeni &amp; Ghasemy Yaghin, 2021; Srai &amp; Lorentz, 2019)</td>
</tr>
<tr>
<td>The use of blockchains for smart contracts and secure financial transactions platforms that facilitate cryptocurrencies (Gunasekara et al., 2021)</td>
</tr>
<tr>
<td>Combining environmental product declaration and life cycle assessment for benchmarking platforms (Welling &amp; Ryding, 2021). Integrating blockchains horizontally and vertically in building information systems (Pellegrini et al., 2020)</td>
</tr>
<tr>
<td>The use of blockchain in Supply chain traceability platforms (Pellegrini et al., 2020; Sander et al., 2018)</td>
</tr>
<tr>
<td>Applying analytics to market data to create wall to wall mapping for supplier monitoring and network visualization ([Zu Ermgassen et al., 2020)</td>
</tr>
<tr>
<td>Online e-commerce communication chat and upstream B2B communication platforms (Koponen &amp; Rytsy, 2020)</td>
</tr>
<tr>
<td>E-receipt cloud-based solutions using retail invoices (Gavrila Gavrila &amp; de Lucas Ancillo, 2021)</td>
</tr>
<tr>
<td>Integrated cloud Enterprise Planning Electronic purchasing system platforms (Keitemoge &amp; Narh, 2020)</td>
</tr>
<tr>
<td>Multi-Criteria Decision Making (MCDM) techniques (Dotoli et al., 2020) through the use of statistical analysis to solve the supplier selection problem.</td>
</tr>
<tr>
<td>Supply Network Link Predictor (SNLP) (Brintrup et al., 2018) using machine Learning classification algorithms such as Naïve Bayes and Logistic Regression</td>
</tr>
<tr>
<td>Prediction tools to predict purchase orders and increase trust in B2B (Liu et al., 2020) using supervised machine learning regression models random forest and quantile regression forest (QRF)</td>
</tr>
<tr>
<td>Robotic Process Automation (RPA) (Viale &amp; Zouari, 2020) to automate procurement processes.</td>
</tr>
<tr>
<td>Cloud web-based automated purchasing and ordering system (Oh, 2019) using artificial intelligence and the cloud</td>
</tr>
<tr>
<td>Marketing intelligence platforms (Suzuki et al., 2019) based on Artificial intelligence</td>
</tr>
</tbody>
</table>
4.6. RQ2: What is the impact of procurement 4.0 on economic, social and environmental sustainability dimensions?

Sustainable procurement is about guaranteeing that the product and services consumed by organizations are sustainable. This includes the financial economic benefits, lowest environmental impact and positive social contribution.

Digital procurement in the era of procurement 4.0 can progressively contribute to the development of sustainable procurement and positively impact the triple bottom line of sustainability.

Firms are establishing dedicated Industry 4.0 and procurement digitalization technologies such as IoT, Big data and blockchains to support real time data collection, storage and security across the supply chain, supply base and buyers’ suppliers’ communications and interactions. Data quality, veracity, integrity, and security are crucial for the establishment of visibility. Data Quality is critical to manage the risk and uncertainties in material purchasing. Algorithm can be used to maximize procurement data quality collected through IoT, RFID, mobile devices from multiple suppliers, including costs, capacities, risk level and prices. The Algorithms developed to determine the optimal integrated purchasing plan in a multi-product setting under risk. Data quality and accuracy will establish accurate procurement decision making with high confidence level that will positively minimize purchasing risk, reduce total cost of purchase. Thus, impacting all sustainability dimensions (Shabani-Naeeni & Ghasemy Yaghin, 2021).

The use of Environmental Product Declarations can support buyers to make decisions to reduce environmental footprint, especially if combined with Product Category Roles (PCRs) that describe product background data, accurate product description, specify flows (Rangelov et al., 2021). This traditional approach facilitates environmental improvements and procurement decision making process. Life cycle applications (LCA) combined with tools that streamline Environmental Product Declarations’ and procurement practices can play an important role in efficient material footprint reduction (Welling & Ryding, 2021).

Additionally, blockchain technologies will support the digitalization of documentation and poor integration by the development of traceability applications where product meta data can be collected in real-time, stored and shared across the parties including suppliers and customers.
across the supply chain (Sander et al., 2018). This will reduce paper-based documentation, secure data and prepare for higher transparency and trust that will enable effective purchasing and stronger buyer suppliers’ relationships. It will improve planning and the control of distribution, order management, order delivery fulfillment and tackle the Bullwhip effect, consequently, enhancing intra-organizational and inter-organizational integration (i.e., cross-functional and cross-enterprise) and impacting economic and environmental dimensions of sustainability (Fatorachian & Kazemi, 2021).

The use of wall-to-wall mapping of available market data such as the use of Transparency for Sustainable Economies “Trase.earth” initiative reveals the relationships and connection between the actors within the supply chain, including the regions and areas of sourcing, process operations where there is a significant environmental footprint (Zu Ermgassen et al., 2020). Data from the supply base and transactions from international trade in the food industry can help to drive positive sustainability impact, including information about changes on the land, carbon emissions and biodiversity loss. The information will support the procurement function to improve the monitoring capabilities of the suppliers and the actors’ impacts over the long-term. The function will implement environmentally sustainable sourcing practices (Zu Ermgassen et al., 2020; Sander et al., 2018).

The development of Blockchain based applications and platforms will positively impact the development of procurement 4.0 and increase transparency in procurement. The first important use of Blockchain technology is in the platform of smart contracts. The use of smart contracts in all stages of contact process. The pre-tendering phase where the parties communicate the product or service requirements, buyers can register the requirements as unified messages in the digital register. Secondly, the tendering phase where the buyers will identity the suppliers and service providers. Finally, during the post awarding phase, where the buyers will establish the contract management through the execution and automation of smart contract management. The use of blockchain extend to the security of the ordering process and financial payment transactions. This could be through the use of online smart payments or the possible use of cryptocurrencies. These platforms improve traditional and e-procurement processes as they tackle issues in relation to data security, poor integration and communication. It increases trust in buyers-suppliers’ relationships and solve delays and poor integration. Smart contracts will
improve the organization financial and economic performance and will reduce the total cost of contractual agreements (Gunasekara et al., 2021).

Many organizations are spending money on marketing themselves as being environmentally friendly, a phenomenon known as greenwashing, instead of reducing their actual environmental footprint. Corporate Social Responsibility (SCR) is central to brand differentiation. Conscious consumers are concerned about social responsibility including the workers conditions and the environment of the manufactured product or brand. Blockchain based traceability platformers in supply chain will support achieving corporate social responsibility. It will help sourcing and procurement to manage their supply base and monitor the supplier activities through the automation of due diligence, inspection, contract renewals and auditing. Consumers downstream will have the opportunity to access value chain CSR data in real time about their favorite brand. Blockchain based traceability will increase social responsibility and positively impact consumers’ preferences and the purchasing decisions (Toussaint et al., 2021).

Supplier monitoring activities (SMA) are important to achieve supply chain transparency via product-related, financial, and leadership disclosures of firm performance. The disclosure can positively affect consumers' attitude and purchase intention. Corporate Social responsibility CSR tools include an adoption of various practices involving the environment, the community, human rights, and employees’ treatment (Duan et al., 2021). This will positively impact the economic, social and environmental sustainability. Transparency can improve confidence on sources of materials and critical minerals which will improve the security of supply by knowing more about physical flows and the business information and the actors in the global markets. Due diligence has emerged as an approach that is expected of companies, both upstream and downstream involved in the mineral supply chains where there is a high risk of conflict, human rights violation or need for governance (Young et al., 2019).

The procurement function in the construction industry has benefited from blockchain technologies in in both managing information and traceability. Urbanization has created a lot of waste in construction due to higher demand and unsustainable consumption of natural resources. Blockchain based building Information management systems are used to promote waste minimization by evaluating the efficiency of most economically advantageous tender during the tender phase (Pellegrini et al., 2020). In Addition, during demolition, transparent
information sharing platform with the aid of global positioning systems (GPS) can collect and update real time information about the waste and demolition material on sites to facilitates environmental decision making and circularity in public procurement. Such digital platforms information includes the weight of construction and demolition waste and the delivery time by trucks connected by GPS. This will shorten negotiation time, foster trust and relationships, reduce opportunistic behavior, prevent corruption, prevent bribery and offer accessibility for governments in public procurement. The platform lower transaction cost and establish circular economy (CE) (Bao et al., 2019).

Downstream operations and transparency are important for procurement decision making and sustainability. Sales data from purchases are important source of data when correlated to customers. Suppliers can trace the purchase transactions, apply statistics, extract patterns from invoices to understand their customers behavior. This can provide personalize products and services. The concept of cloud based digital servitisation such as software-as-a-service (SAAS), multi-channel communication and interaction with customers through the use of cloud-based e-receipt platform will help firms growing their business by reducing paper waste and create a new value propositions and business opportunities. Suppliers can enhance customers or buyers’ loyalty based on data and analytics. This will create new business model innovation, new consumption and facilitate a shared economy. Finally, cloud-based solutions are more secure, handled or outsourced by experts instead of the local IT team, offering more security and social responsibility in relation to the security of sensitive customer data (Gavrila Gavrila & de Lucas Ancillo, 2021).

Downstream Business to Business communication is also important for the procurement function sustainability. New medium of communication between buyers and supplier’s and computer-mediated communication (CMC) such as online chat in form of messages and texts are used in e-commerce. This concept of social presence increases the customers’ initial trust in the company website or in the seller in online platforms. Communications and messages that are unsynchronized or anonymous can hinder relationships. As a result, it is important to develop customized online communication based on the buyer relationship phase or the buyer type. New buyers will have different requirement and communication comparing to existing customers or buyers. This approach will strengthen the customer relationship, experience, loyalty and possible purchase, impacting the economic and financial performance of the firm (Koponen & Rytsy, 2020).
The sustainability impact of optimizing procurement processes through information modelling, statistical analysis and algorithms has been used and discussed in the literature. There are three necessary resources which are talented employees, management commitment and technological development that has significant contribution towards achieving optimized Procurement 4.0. Procurement 4.0 will optimize the use of natural resources, energy usage and procurement cycle times. Manufactures will become more agile with customer driven procurement. Procurement 4.0 will increase productivity, increase margins, shorten product life cycles, eliminate waste and facilitate the move from a linear economy to a circular economy (Bag et al., 2020).

From the analytics perspective, Multi-Criteria Decision Making (MCDM) are mathematical techniques for the applications of Supplier Selection Problem (SSP). Manufactures aim is to acquire the right goods and services, work with the right suppliers, buy at the right price and taking into consideration environmental and social impact. MCDM support the establishment of governance and compliance with the principles of free competition, non-discrimination and transparency of the awarding procedures. MCDM help the procurement professional to evaluate and rank the alternative multiple conflicting criteria for selecting the optimal Supplier (Dotoli et al., 2020).

The supplier selection problem (SSP) is a key issue in procurement optimization. Manufactures often lack visibility of the procurement interdependencies between the suppliers within their supply network. However, the knowledge of these interdependencies within the supply network is useful to plan for potential operational supply chain risk and disruption and the possibility of using data analytics for improving supply chain. Manufactures will be able to apply machine learning algorithms to select the optimal supplier that can deliver products as per the requirements despite the constraints. (Brintrup et al., 2018).

Original equipment manufacturers (OEMs) and Small and Medium Size Enterprises (SMEs) require prediction models for the completion time of work orders such as purchase orders and sales orders. Surrogate models in the form of supervised learning based on decision trees are trained on historical transactional data. This will increase the overall trust within the supply base and parties in the supply network and optimize the procurement decision making process (Liu et al., 2020).
Cloud integrated enterprise resource planning systems (ERPs) are information systems that can optimize purchase processes. Cloud based ERP have accessibility to supplier’s information such as qualification, profiles, risk factors, and policy compliance to aid choose best suppliers. Cloud based ERP will reduce costs, improve decision making, reporting, buyer supplier relationships, achieve market and legal needs and optimize process efficiency. Socially, cloud-based ERP systems are hosted by a third-party service provider via the Internet who are responsible about maintaining updates, servers, maintenance and backups. This offers higher data security and cut costs (Keitemoge & Narh, 2020).

Robotic Process Automation (RPA) and its use in procurement practices is under development. The aim is to automate existing procurement processes without disrupting existing information technology. This will create clear, established and immutable process. RPA impact operational procurement including saving time and eliminating buyers’ repetitive and non-productive tasks. RPA will optimize procurement processes, increase flexibility and reduce human errors. This will strengthen buyers’ supplier relationships. However, RPA is likely to impact employees and cause loss of jobs as it will reduce the number of employees. For example, the number of employees required to monitor type C items that has less economic value (Viale & Zouari, 2020).

Automated purchasing and ordering systems that are based on industry 4.0 which are web-based systems that shares information about planning, production, orders, delivery, quality, inventory levels in real time among all parties in the supply network. These autonomous, interconnected systems support the automation of procurement processes through the analysis of big data and the use of artificial intelligence. It will have a positive impact on sustainability through maximizing profits, efficient inventory management and on time delivery of product and services. The proposed model strengthening business partner services through shared ordering, online tracking of delivery, flexibility in production planning, real-time payment status and payment confirmation. Additionally, it will improve the productivity of procurement, logistics services and traceability. Furthermore, the system is based on real time monitoring which will improve key performance indicators, real time progress management of order to delivery (OTD), risk assessment and rapid decision support for emergency situations and evaluation based on real data. Finally, efficient inventory management and reduction by ensuring accuracy, reliability and control of inventory, improve lead times, delivery and quality.
Finally, downstream cloud-based marketing automation platforms are important in purchasing decisions due to the utilization of customers behavior which support to customize and personalize the purchase offerings (Suzuki et al., 2019).

Table 3 summaries the procurement 4.0 applications and analytics and the impact of procurement 4.0 on economic, social, environmental sustainability dimensions.

Table 3. Procurement 4.0 and Sustainability

<table>
<thead>
<tr>
<th>Procurement 4.0 Applications, platforms, optimization and automation</th>
<th>Impact on Sustainability dimensions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Using algorithm to maximize data quality to manage risk and uncertainties in material purchasing.</td>
<td>Establish accurate procurement decision making with high confidence level. Minimize purchasing risk, reduce total cost of purchase, foster economics sustainability (Shabani-Naeeni &amp; Ghasemy Yaghin, 2021).</td>
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<tr>
<td>Using a combination of environmental product declaration and life cycle assessment as benchmarking tools to streamline Environmental Product Declarations’, LCA and procurement practices</td>
<td>Efficient material footprint reduction, facilitates environmental improvements and procurement decision making process and foster environmental sustainability (Welling &amp; Ryding, 2021; Rangelov et al., 2021).</td>
</tr>
<tr>
<td>Smart contracts and secure financial transactions platforms that facilitate cryptocurrencies.</td>
<td>Improve the contract process and management, data security, poor integration and communication. It increases trust in buyers-suppliers’ relationships (Gunasekara et al., 2021).</td>
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<tr>
<td>Supply Chain traceability applications</td>
<td>Facilitate corporate social responsibility (CSR) practices. Allow procurement to manage their supply base and monitor the supplier activities through due diligence, inspection, contract renewals and auditing. Consumers to access value chain CSR data positively impact consumers’ preferences and purchasing decisions (Toussaint et al., 2021; Sander et al., 2018; Egels-Zandén &amp; Hansson, 2016). Supplier monitoring activities (SMA) achieve supply chain transparency via product and financial disclosures of firm performance. Positively affect consumers' attitude and purchase intention. (Duan et al., 2021)</td>
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<tr>
<td>Blockchain based building Information management or applications for environmental traceability and circularity.</td>
<td>Waste minimization by evaluating the efficiency of the most economically advantageous tender (Pellegrini et al., 2020). During demolition, transparent information sharing platform with the aid of global positioning systems (GPS) collect and update in real time information about the waste and...</td>
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<tr>
<td>Technology/Method</td>
<td>Description</td>
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<td>demolition material on sites to facilitates environmental decision making in public procurement. Shorten negotiation time, foster trust and relationships, reduce opportunistic behavior, prevent corruption, prevent bribery and offer governments accessibility. Lower transaction cost establishing circular economy (CE) (Bao et al., 2019).</td>
<td>Wall-to-wall mapping of market data for supply network visualization.</td>
</tr>
<tr>
<td>Reveals the supply network actors’ relationships and connection including regions, sourcing areas, process operations with significant environmental footprint. In food industry visualize land condition, biodiversity loss, and carbon emissions. Improve supplier monitoring capabilities. Support sustainable environmental sourcing practices (Zu Ermgassen et al., 2020).</td>
<td>Upstream B2B communication applications, online chat in business-to-business e-commerce.</td>
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<tr>
<td>Increases the customers’ initial trust in a company website or in the seller in online platforms. Customized online communication based on the buyer relationship phase or buyer type will strengthen the customer relationship, experience, loyalty and potential purchase, impacting financial performance and economic sustainability. (Koponen &amp; Rytsy, 2020).</td>
<td>E-receipt cloud-based solutions.</td>
</tr>
<tr>
<td>Reduce costs, improve decision making, reporting, buyer supplier relationships, achieve market and legal needs and optimize process efficiency. Socially, Cloud ERP are hosted by a third-party responsible about maintaining updates, servers, maintenance and backups. This offers higher data security and cut costs (Keitemoge &amp; Narh, 2020).</td>
<td>Multi-Criteria Decision Making (MCDM) techniques.</td>
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<tr>
<td>MCDM support the establishment of governance and compliance with the principles of free competition, non-discrimination, free competition, and transparency of the awarding procedures. MCDM help the procurement professional to evaluate and rank the alternative multiple conflicting criteria for selecting the optimal Supplier (Dotoli et al., 2020).</td>
<td>Supply Network Link Predictor (SNLP). Plan for potential operational supply chain risk and disruption and the use of data analytics in procurement and supply chain (Brintrup et al., 2018).</td>
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<tr>
<td>Increase trust in the supply base and supply network and optimize the procurement decision making process (Liu et al., 2020).</td>
<td>Predict work schedule, purchase orders and increase trust in B2B.</td>
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<tr>
<td>Automate procurement processes without disrupting existing information technology. Create clear, established and immutable process. Saving time of operations, eliminating buyers’ repetitive and non-productive tasks.</td>
<td>Robotic Process Automation (RPA).</td>
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<tr>
<td>Cloud web-based automated purchasing and ordering system.</td>
<td>Optimize procurement processes, increase flexibility, reduce human errors and strengthen buyer’s supplier relationships. However, RPA is likely to impact employment and cause loss of jobs (Viale &amp; Zouari, 2020).</td>
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<tr>
<td>Cloud-based marketing automation platforms.</td>
<td>Information sharing of planning, production, orders, delivery, quality, inventory levels in real time across parties in the supply network which will improve key performance indicators, real time management of order to delivery, risk assessment and rapid decision support for emergency situations. Support automation of procurement processes, maximizing profits, efficient inventory management and on time delivery of product and services leading to positive economic sustainability (Oh, 2019).</td>
</tr>
<tr>
<td></td>
<td>Important in purchasing decisions due to the utilization of customers behavior which support to customize and personalize the purchase offerings (Suzuki et al., 2019).</td>
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<td>Reference</td>
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<tr>
<td>(Rangelov et al., 2021)</td>
<td>Journal of Cleaner Production</td>
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<tr>
<td>(Shabani-Naeeni &amp; Ghasemy Yaghin, 2021)</td>
<td>Journal of Business &amp; Industrial Marketing</td>
</tr>
<tr>
<td>(Fatorachian &amp; Kazemi, 2021)</td>
<td>Production Planning &amp; Control</td>
</tr>
<tr>
<td>(Gunasekara et al., 2021)</td>
<td>Journal of Facilities Management</td>
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<tr>
<td>Authors</td>
<td>Journal</td>
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<tr>
<td>Toussaint et al., 2021</td>
<td>European Research on Management and Business Economics</td>
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<tr>
<td>Gavrila Gavrila &amp; de Lucas Ancillo, 2021</td>
<td>Technological Forecasting &amp; Social Change</td>
</tr>
<tr>
<td>Welling &amp; Ryding, 2021</td>
<td>The International Journal of Life Cycle Assessment</td>
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<tr>
<td>Authors</td>
<td>Journal/Conference</td>
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<tr>
<td>Zu Ermgassen et al., 2020</td>
<td>Proceedings of the National Academy of Sciences of the United States of America</td>
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<tr>
<td>Pellegrini et al., 2020</td>
<td>Sustainable Energy Systems and Policies, a section of the journal Frontiers in Energy Research</td>
</tr>
<tr>
<td>Viale &amp; Zouari, 2020</td>
<td>Supply Chain Forum: An International Journal</td>
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<td>Source</td>
<td>Journal/Media</td>
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<tr>
<td>(Liu et al., 2020)</td>
<td>Journal of Computing and Information Science in Engineering</td>
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<tr>
<td>(Koponen &amp; Rytty, 2020)</td>
<td>European Journal of Marketing</td>
</tr>
<tr>
<td>(Dotoli et al, 2020)</td>
<td>Applied Soft Computing Journal</td>
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</table>
process of Public Procurement (PP) tenders, to solve Supplier Selection Problem (SSP).

(AHP), the Preference Ranking Organization Method for Enrichment of Evaluations (PROMETHEE), the Multi Attribute Utility Theory (MAUT), and the Data Envelopment Analysis (DEA) Selection Problem (SSP) including the Analytic Hierarchy Process (AHP), the Preference Ranking Organization Method for Enrichment of Evaluations (PROMETHEE), the Multi Attribute Utility Theory (MAUT), and the Data Envelopment Analysis (DEA) compliance with the principles of non-discrimination, free competition, and transparency of the awarding procedures.

<p>| (Bag et al., 2020) | Production Planning &amp; Control | Examining the role of procurement 4.0 to drive productivity in remanufacturing operations for a circular economy (CE), sustainable solution for remanufacturing firms by developing resources for procurement 4.0 | Survey data gathered from working professionals in South Africa. The results are that technological resources are necessary in procurement 4.0, which can, in turn, improve productivity in remanufacturing. | Market data availability combined with intelligence and trends on global supply pricing will provide buyers with advantage of being able to control supply chain costs in remanufacturing operations. | Digital Procurement 4.0 (P4.0) can improve the business performance through higher visibility and resilience. P4.0 support material planning and lead times reduction. It will increase visibility and eliminate bottlenecks. Buyers can optimize energy, natural resources usage, and purchase cycle time. P4.0 will optimize manufacturing processes, increase profit margin, shorten product lifecycle, high productivity and waste elimination by moving from linear to circular economy (CE) |</p>
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<tr>
<th>Source</th>
<th>Title</th>
<th>Methodology</th>
<th>Findings</th>
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<tr>
<td>(Keitemoge &amp; Narh, 2020)</td>
<td>Advances in Science, Technology and Engineering Systems Journal</td>
<td>Effective information systems application for purchase process optimization</td>
<td>Sharing insight on effective application of information system for purchase process optimization Cloud-based information systems for purchase process optimisation integrated with existing enterprise resource planning systems (Cloud Integrated ERP System) offers accessibility to suppliers’ data and information including qualification, questionnaires, profiles, risk factors, and policy compliance. This aids the choice of suppliers. Manufacturing organizations can implement machine learning algorithms to process, analyze, funnel down and select the optimal suppliers that deliver products that meets the requested requirements. Optimal Supplier (OS) is a supplier who can supply right material, best price, right quality despite all constraints.</td>
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<tr>
<td>(Duan et al., 2021)</td>
<td>Journal of operations Management</td>
<td>The research focuses on the effect of supplier monitoring activities (SMA) and disclosures of activities on consumers’ attitude toward the firm and the consumer purchase intention.</td>
<td>Hypotheses testing by conducting three vignette based role-playing experiments with Amazon M-Turk participants. Supplier monitoring activities (SMA) by using data and information on suppliers’ activities across the supply chain are central for supply chain transparency. Disclosure of product-related, financial, and leadership information have positive impact on firms’ performance Corporate social responsibility (CSR) consists of a variety of environmental and social practices that involve the environment, the society, human rights, employees’ working conditions, equality and diversity. CSR requires greater resources and disclosure that significantly affects consumers’ attitude toward the firm, brand or the purchase intention. As a result, impact economic performance, Environmental and social dimension of sustainability.</td>
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<tr>
<td>(Bao et al., 2019)</td>
<td>Waste Management</td>
<td>The research explores innovative procurement models to deal with construction and demolition (C&amp;D) waste through relational type of contract arrangements. The research reports some</td>
<td>Case study in Suzhou China research allows the exploration and understanding of complex issues based on the primary data collected. A combination of Transparent digital information sharing platforms combined with positioning technologies such as global positioning system offers shared and updated information in real-time manner. Information on the shop floor such as the weight of construction and The relational contract (RC-Type) of concession framework shortens the negotiation time, foster trust between the relevant parties include, lower transaction cost and allow for sustainable development of the circular economy, and solve the problems of managing supplier’s</td>
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<tr>
<td>Author(s)</td>
<td>Journal</td>
<td>Case Study/Discussion</td>
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<td>Oh, 2019</td>
<td>International Journal of Recent Technology and Engineering (IJRTE)</td>
<td>Proposed smart supply chain management model to accommodate current high technological issues and business requirements under fourth industrial revolution era. The model consists of automatic ordering, purchasing system and artificial intelligence (AI) based appropriate inventory computation system, and detachable IoT based inventory management system. The Internet of things (IoT) is described as next generation of Internet connected embedded ICT systems in a digital environment to integrate supply chain and logistics processes. Big data refers to information processing environment include variety of data generated from sources including IoT sensors, mobile devices, online social networks, etc. The authors proposed web based SCM consists of automatic ordering purchasing system, artificial intelligence based inventory computation system, and detachable IoT intelligent inventory management system as smart SCM solution. The model aim at maximizing corporate profits through efficient inventory management and on time supply and delivery of products. It solves complex management issues including developing stronger business partner services, shared ordering, delivery and information through online service. It offers flexibility in supplier production planning through, real-time payment status and advance payment confirmation, improve productivity of purchasing, logistics services. It offers real-time history management and traceability, reduction of lead time and cycle time.</td>
<td></td>
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<tr>
<td>Suzuki et al., 2019</td>
<td>Fujitsu Scientific &amp; Technical Journal</td>
<td>Digital contact points are gaining importance in the purchasing decision making process. Many B2B companies are working on digital A company case study using a cloud-based marketing automation platform known as FUJITSU Intelligent Data Service Marketo. Data acquired by digital contact points, data management platforms (i.e., e-mail and response data, external or own site behavior data), Customer relationship management data It improve trust and loyalty of current existing customers and efficient acquisition of future new customers. It supports the accumulation and visualization of consumer behavior data and grasp customer behavior</td>
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marketing using effective and intelligent B2B platforms.

CRM (i.e contract data, purchase history data). FUJITSU Intelligent Data Service Marketo, a cloud-based marketing automation platform that supports to maximize the effect of digital marketing in BtoB, improve loyalty and trust of existing customers, and the acquisition of new customers.

during the purchase process. This supports the evaluation of potential customers and consider measures of implementing automation.

| (Srai & Lorentz, 2019) | Journal of Purchasing and Supply Management | The paper develops an approach to evaluating designs for digitalization interventions in purchasing and supply management (PSM). The authors identify some fundamental design principles and seven value drivers for PSM are identified for the proposed grid to facilitate the design of applications and interventions for digitalising PSM. | The proposed approach was tested and its utility is demonstrated through literature and multiple case-study to demonstrate the usefulness of the analytical framework. Four leading multinational firms were engaged in focused group full day workshops. | An approach for evaluating the designs for digitalisation interventions in procurement and supply chain through the use of variety of industry 4.0 technologies such as big data, cloud and IoT that create opportunities for procurement applications. Virtual company mall a cloud-based set of pre-approved shops and interfaces for preferred suppliers. Cognitive procurement assistant, application being enabled by cloud for the automation of orders approval and release. Supply analytics ‘app bundle’ enables access and analysis of a variety of data, uses mobile dashboards for decision makers and combining cognitive computing capabilities for | Sustainability addressed through theory-based purchasing value drivers. Operational transaction management influence operational and capital costs through efficient requisition, procurement to pay handling with consideration of inventory and payment time. Supplier capability assessment based on Transaction Cost Economics (TCE) by reduction in information asymmetry in exchange relationships and evaluation of supplier capabilities. In the Resource based view, the alignment of a firm’s external resource pool to enhance cost efficiency, innovation, sustainability, relationship management focuses and managing power. Knowledge based perspective by aligning supplier incentives with the buyer. The agency theory, a view ensuring a return on partnerships, process improvement, |
Virtual supplier room app bundle allows the firm to interact with strategic suppliers, share information and insights about costs, risks and technologies. Virtual reality application for supplier audit, virtual category room application bundle, keep tracking of category management. Supplier network applications that connect the applications via e-procurement types of solution for e-sourcing and supplier management.

<table>
<thead>
<tr>
<th>(Young et al., 2019)</th>
<th>Resources</th>
<th>A standards program for firm collaboration to overcome barriers including geography and cultural distance in supply chain management</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Resources</td>
<td>A mixed model, data from firms’ upstream and downstream mineral supply chain. Upstream, an analysis of a population of 323 “deep suppliers”. Downstream, interviews with six conflict mineral managers in multinational manufacturers who are end-users of tantalum, tin, tungsten, and gold.</td>
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<td></td>
<td>Traceability and tracking of critical minerals sources within the supply network is a difficult task including the number of actors due to the complexity of international trade and number of intermedries and confidentiality, physical reasons, mixing of mineral ores, mixing virgin materials with recycled sources, chemical processes and physical conversions such as melting</td>
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<td>Transparency via traceability can improve confidence on the sources and origin of materials, which may improve security of supply by knowing more about both physical flows and business information on actors in global markets. Due diligence as an approach that is expected of companies, both upstream and downstream, involved in mineral supply chains where there is a risk of conflict, human rights, governance or other concerns.</td>
<td></td>
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<tr>
<td>(Sander et al., 2018)</td>
<td>British Food Journal</td>
<td>Investigate meat traceability by exploring different perspectives and opinions from meat supply chain stakeholders (SCSs). The research evaluates the potential of acceptance of blockchain technology as a viable transparency and traceability system (TTS)</td>
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<tr>
<td>(Brintrup et al., 2018)</td>
<td>Complexity</td>
<td>Manufacturers lack visibility of the procurement interdependencies with their suppliers and supply network. The knowledge of the interdependencies is useful to plan for potential operational disruptions.</td>
</tr>
<tr>
<td>(Egels-Zandén &amp; Hansson, 2016)</td>
<td>Journal of consumer policy</td>
<td>Research focusing on supply chain transparency as a corporate tool and the consumer willingness to buy</td>
</tr>
</tbody>
</table>
5. Discussion

5.1. A conceptual model of procurement 4.0

The research aimed to advance knowledge creation in the area of procurement 4.0 through a systematic literature review of the potential of industry 4.0 digitalization technologies, applications and analytics in procurement digitalization and its impact on sustainability. The findings from the literature will be used in the development of a proposed procurement 4.0 model based on Industry 4.0 technologies, applications, mathematical algorithms, statistical analytics and procurement processes automation. The model will contribute to address the gap in the literature about the lack of the visualization of procurement 4.0 (Tripathi & Gupta 2020; Srai & Lorentz, 2019) and lack of blockchain development in procurement (Srai & Lorentz, 2019). According to Tripathi & Gupta (2020) the existing literature discusses the implementation, impact and advantages of a technology or number of combinations of industry 4.0 technologies on procurement process but lacks the visualization of the transformation process of combining the technologies (Tripathi & Gupta 2020). So, these gaps are addressed by combining the knowledge in the literature to conceptualize a proposed procurement 4.0 model.

As the procurement digitalization process is complex and requires technological capabilities, talented people and management commitment, this section will discuss the findings of the literature from a digital maturity perspective and capabilities of smart connected procurement. Capabilities of smart connected procurement can be classified in to four areas monitoring, control, optimization and autonomy which was the basis of connected smart products and manufacturing (Porter & Heppelmann, 2015). Each one of them build upon the previous stage. As a result, the proposed procurement 4.0 model is based on the capabilities of smart connected procurement and the digital maturity model.

5.1.1. Procurement Monitoring (Visibility)

Represented by the use of internet of things (IoT), sensors and external data sources that will enable comprehensive monitoring of procurement activities through big data veracity, variety, quality, integrity and security (Fatorachian & Kazemi, 2021; Shabani-Naeeni & Ghasemy Yaghin, 2021). The literature highlighted the importance of data quality in procurement to manage risk in purchasing (Shabani-Naeeni & Ghasemy Yaghin, 2021), the development of
blockchain technology and its use in procurement as smart contracts (Gunasekara et al., 2021), for waste management strategies (Pellegrini et al., 2020) and traceability (Sander et al., 2018). Blockchain will guarantee the security of data through data immutability and hash mechanism.

5.1.2. Procurement Control (Transparency)

Software applications embedded in the procurement function could enable the control of the procurement function and customize the interactions upstream with the suppliers and downstream with customers. This will increase transparency and information exchange in procurement and across the supply chain. Applications based on blockchain technology such as smart contract applications (Gunasekara et al., 2021), information management in the construction industry that integrates blockchain vertically and horizontally for waste management, circularity and shared economy (Pellegrini et al., 2020) and the use of blockchain for transparency and traceability systems (Sander et al., 2018). Furthermore, the use of product declarations (EPDs) in green public procurement (GPP) (Rangelov et al., 2021) combined with applications of Life Cycle Assessment (LCA) as benchmarking tools to monitor environmental footprint (Welling & Ryding, 2021). Additionally, analyzing available market data for wall-to-wall mapping of supply chain network to manage the supply base and to quantify purchase risk (Zu Ermgassen et al., 2020). Finally, the use of digital e-receipts (Gavrila Gavrila & de Lucas Ancillo, 2021) and online e-commerce communication between buyers and supplier for customization of communications and offerings (Koponen & Rytsy, 2020). All of these applications will increase transparency and information exchange across the actors in the supply base and the supply network.

5.1.3. Procurement Optimization (Predictive Capacity)

The above stages of monitoring and control will enable algorithms to optimize processes and support the decision making of the procurement function. This will enhance the procurement function performance and will allow for predictive analytics in procurement. Procurement optimization was discussed through the use of Multi-Criteria Decision Making (MCDM) to improve the selection criteria and decision-making process in complex procurement environments (Dotoli et al, 2020), the Supply Network Link Predictor (SNLP) method to study the interdependencies between suppliers within the supply network and its impact on relationships (Brintrup et al., 2018), the use of predictive analytics to predict the final time of completion of work in the supply network (Liu et al., 2020) and finally, applying algorithms to improve data quality in procurement. (Shabani-Naeeni & Ghasemy Yaghin, 2021)
5.1.4. Procurement Autonomy (Adaptability)

Combining the above stages of monitoring, control and optimization allows for the autonomous, interconnected and autonomy of procurement. Procurement automation is researched through the use of robotic process automation (RPA) (Viale & Zouari, 2020), the use of automated purchasing systems with artificial intelligence (Oh, 2019), the use of cloud-integrated ERP system for the automation of purchasing (Keitemoge & Narh, 2020), the use of intelligent marketing platforms in business-to-business relationships for automated communication and customization of customers offerings (Suzuki et al., 2019). Procurement autonomy support the development of a cyber physical system of the procurement function and further support the development of a digital twin of the procurement function and end to end supply network.

Table 5 represent a digital maturity model of procurement 4.0 as part of the overall supply chain and manufacturing digital ecosystem. The maturity model is based on a combination of the result of the systematic literature review on the concepts of digital applications and analytics for procurement 4.0, the digital maturity index for industry 4.0 (Schuh et al., 2018) and the data analytics discussion by (Pause & Blum, 2019) that were discussed in the theoretical background chapter.

Finally, Figure 13 conceptualize a procurement 4.0 model based on the findings from the systematic literature review. The model conceptualizes the capabilities of smart connected procurement classified in to four areas monitoring, control, optimization and autonomy for a truly data driven procurement. The model supports the conceptualization and the implementation of procurement 4.0 by highlighting four stages for smart connected procurement. First, procurement monitoring represented by the use of Industry 4.0 technologies and data visibility as enabler for the implementation of digital applications. Secondly, procurement control described by transparency and information exchange between the actors in the supply network through the implementation of digital applications and online platforms for transparency. Thirdly, Procurement optimization discussed through the use of mathematical regression and statistical analysis that optimize the digital applications for optimized procurement decision making process. Finally, procurement autonomy represented by high level of robotic process automation leading to procurement 4.0 transformation, allowing for the possible implementation of a cyber physical systems or a digital twin of procurement.
Table 5: Digital Maturity Model for Procurement 4.0

Based on the systematic literature review and the industry 4.0 maturity index

<table>
<thead>
<tr>
<th>Digital and Data Analytics Maturity Stage</th>
<th>The Supplier organization (Procurement 4.0)</th>
<th>The Buyer organization (Procurement 4.0)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Procurement Autonomy (Adaptability)</td>
<td>Procurement repetitive tasks automated with Robotic Process Automation (RPA). Automated purchasing system integrated with cloud enterprise resource planning and inventory management based on artificial intelligence and intelligent marketing platforms and analytics derived from real customer demand, customized communication and offerings. An Integrated digital ecosystem of procurement 4.0, supply chain and manufacturing connected upstream with suppliers and downstream with customers. Creating a digital value chain based on automation and connectivity using Industrial Internet of things (IoT), Big data analytics and Artificial Intelligence.</td>
<td>Using algorithms to improve data quality for purchasing, multicriteria decision making (MCDM), supplier network link predictor (SNLP - Naive Bayes and Logistic Regression), Predictive analytics for purchase and sales orders completion and part delivery.</td>
</tr>
<tr>
<td>Procurement Optimization (Predictive Capacity)</td>
<td>Supplier can use algorithm to optimize their supply base and network. Repetitive tasks of orders processing are automated based on the full integration of procurement 4.0, the supplier is focusing on value added activities in the relationship.</td>
<td>Using algorithms to improve data quality for purchasing, multicriteria decision making (MCDM), supplier network link predictor (SNLP - Naive Bayes and Logistic Regression), Predictive analytics for purchase and sales orders completion and part delivery.</td>
</tr>
<tr>
<td>Diagnostic Analytics</td>
<td>Big data analytics with many to many applications and platforms. Cloud-based digital e-receipt. Transparency and Information exchange with byers via communication and online chat in B2B. Smart contracts, traceability and transparency applications, environmental systems for circularity and wall to wall mapping of the supply network.</td>
<td>Big data analytics deployed with many to many applications and platform. cloud based purchasing system to manage data and analytics. Smart contracts, traceability and transparency applications, environmental management systems for circularity and wall to wall mapping of the supply network.</td>
</tr>
<tr>
<td>Procurement Monitoring (Visibility)</td>
<td>Sensors enabled processes with dedicated Industry 4.0 technology IoT, Sensors with blockchains for smart contracts and financial transaction. Higher visibility across the supply chain transactions through documents digitalization and Environmental Product Declaration for measuring footprint reduction.</td>
<td>Sensors enabled processes with dedicated Industry 4.0 technology IoT, Sensors with blockchains for smart contracts and financial transaction. Higher visibility across the supply chain transactions through documents digitalization and Environmental Product Declaration for measuring footprint reduction.</td>
</tr>
<tr>
<td>Descriptive Analytics</td>
<td></td>
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</tbody>
</table>

Industry 4.0—Toward Automation
### Procurement Autonomy (Adaptability)
- Robotic Process Automation (RPA)
- Automated Purchasing System with Artificial Intelligence (AI)
- Cloud-Integrated Enterprise Resource Planning (ERP) System for Purchasing Automation
- Intelligent Marketing Communication Platforms in Business to Business (B2B)

### Procurement Optimization (Predictive Capacity)
- Multi-Criteria Decision Making (MCDM) algorithms
- Supply Network Link Predictor (SNLP) regression methods for supply network interdependencies
- Predictive analytics to predict the final time of completion of work, purchase, sales orders and delivery
- Mathematical Algorithms to improve data quality and identify procurement risk

### Procurement Control (Transparency)
- Blockchain Based Smart Contracts and Financial Transactions
- Blockchain based Traceability and Transparency Applications
- Blockchain Integration for Environmental Information Systems and Circularity
- Lifecycle Assessment Applications with Product Declaration as Benchmarking Tools
- Online e-commerce communication for buyers and suppliers
- Wall-to-wall mapping of market data for supply network visualization
- Digital E-receipt cloud-based solutions

### Procurement Monitoring (Visibility)
- Industry 4.0 technologies, Internet of things (IoT), Sensors, Blockchains, Big Data, The Cloud
- Data Management, Quality, Accuracy, Integrity, Security
- Digitalization of Documentation (Environmental Product Declaration and Contracts)
- Integrating Environmental Product Declaration with Product Category Roles in procurement

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Fig 13. Procurement 4.0 Conceptual Model
6. Conclusion

The research on procurement 4.0 concept and the systematic literature review methodology discussed the applications, technologies and analytics that creates procurement 4.0 and how the digital procurement 4.0 influences the procurement function sustainability, business and manufacturing performance including economic, environmental and social sustainability. Based on a systematic literature review, the research offers an overview of digital applications and analytics that will support the transformation toward a procurement 4.0. These include procurement documents digitalization (i.e. environmental product declaration and contracts), Industry 4.0 technologies, digital applications, mathematical algorithms, statistical analysis and procurement process automation.

The findings from the literature review contributed to the development of a proposed procurement 4.0 model based on Industry 4.0 technologies, applications, mathematical algorithms and procurement processes automation. The model contributes to address the gap in the literature about the lack of the visualization of procurement 4.0. A gap that was mentioned by Srai & Lorentz (2019) who highlighted the lack of visualization and a need to develop blockchains technologies in the context of procurement to achieve procurement 4.0. Also, the same gap was mentioned recently by Tripathi & Gupta (2020) who highlighted that the literature discusses the implementation, impact and advantages of individual or a combination of industry 4.0 technologies on procurement process but lacks visualization of the transformation process of combining the technologies.

The proposed model supports the conceptualization of procurement 4.0 by highlighting four stages for smart connected procurement. First, procurement monitoring enabled by data visibility and Industry 4.0 technologies that will support the implementation of the digital applications. Secondly, procurement control described by transparency and information exchange between the actors in the supply network through the implementation of digital applications and online platforms. Thirdly, procurement optimization discussed through the use of mathematical algorithms such as regression and statistical analysis that optimize the digital applications for optimized procurement decision making process. Finally, procurement autonomy represented by high level of robotic process automation and artificial intelligence leading to procurement 4.0 transformation, allowing for the possible implementation of a cyber
physical systems or a digital twin for an integrated procurement, supply chain and manufacturing.

As the model is conceptual, it is based on review of the literature and research studies. Its main contribution in the disciplines of procurement, supply chain, manufacturing, digitalization and sustainability. The digital applications and data analytics discussed in the literature and model has been tested through case studies and within industries. Future research could focus on the implementation of the data analytics section of the model. Additionally, future research could focus on the impact of the model on manufacturing key performance indicators and metrics. Moreover, future research should focus on procurement 4.0 applications and analytics that can further develop and optimize the model. Finally, the future research could focus on the architectural integration of the technologies, applications across procurement, the supply chain and manufacturing taking in to account the reference architectural model of Industry 4.0 (RAMI 4.0) including the challenges of integration. This is seen as a challenge in implementation the model and a source of limitation. In additional to the challenges of digital capabilities such as lack of expertise and the need for a large scale 5G network implementation.

Finally, the model is seen of a high investment for firms on the short-term. So, it might be difficult to implement where relationships between buyers and suppliers are arms-length, transactional or it might not be suitable for small and medium size enterprises (SME’s). However, it can be of a positive return on of investment where relationships are of a strategic nature for tactical and strategic buying categories.

In conclusion, the research and the proposed model represent an attempt by academic research to discuss a topic that is dominant by the consulting sector. It provides a practical knowledge for procurement managers and digital consultants form an academic perspective.
7. References:


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