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Project results

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Business Analytics Skills
for the Future-proof Supply Chains

Project number – 2022-1-PL01-KA220-HED-000088856

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BAS4SC Project Team and research

- Michał Adamczak, Adrianna Toboła-Walaszczyk, Katarzyna Grzybowska, Piotr Cyplik: *Identification of relevance levels in analytical competences for the improvement of higher education programmes in Poland*
- Davor Dujak, Dario Šebalj, Jelena Franjković and Josip Juraj: *Improving Supply Chain Analytics Skills at EFOS through BAS4SC Project*
- Roman Gumzej, Tomaž Kramberger, Kristijan Brglez and Rebeka Kovačič Lukman: *Knowledge-Based Engineering in Strategic Logistics Planning: From Ontology to BAS4SC Insights*
- Dejan Mircetic, Marinko Maslaric and Sanja Bojic: *Machine learning in Business Intelligence*

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Identification of relevance levels in analytical competences for the improvement of higher education programmes in Poland

dr inż. Michał Adamczak
mgr inż. Adrianna Toboła-Walaszczyk
dr hab. inż. Katarzyna Grzybowska, prof. uczelni
dr hab. inż. Piotr Cyplik, prof. uczelni

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Agenda

- Aim of this research;
- BAS4SC Project methodology;
- Research methodology;
- Research results;
- Conclusion and further research;

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Aim of this research

- The **aim** of this research is to identify differences in the perceptions of the relevance of analytical competences by different groups of survey respondents.

- As part of our research, we compared the results of assessments carried out by companies in Poland, Croatia, Slovenia and Serbia in relation to the **level of importance of analytical skills** acquired by university students.

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BAS4SC Project Methodology

- Analysis of over **1,000** higher education programmes from **27** countries in Europe and the USA in the field of data analytics;
- **Surveys** among academic teachers, students and logistics companies in **Slovenia, Croatia, Serbia and Poland**;
- Defining the **competence gap** between currently used educational programmes and the preferences of logistics companies and students;
- Defining four areas of competence within business analytics: **Managerial skills, Mathematical skills (theoretical aspects), Applied math & stat, and IT skills.**

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Research Methodology

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Identification of key competencies within four categories defined in the competence gap

Skills area	Skills
Applied math & stat	AM&S Optimization in logistics
	AM&S Data analysis and statistics
	AM&S Visualization and reporting
IT skills	IT Simulations
	IT BI tools
	IT Data analytics tools
	IT Programming
	IT Database
	IT Visualisation
	IT Management systems
	IT Other IT tools

Skills area	Skills
Managerial skills	MANS Quality and process management
	MANS Data and knowledge management
	MANS Logistics and supply chain management
	MANS Strategic and economic analyses
	MANS Basics of economics
Mathematical skills (theoretical aspects)	MATS Optimization and Operational Research
	MATS Decision and game theory
	MATS AI & ML
	MATS Data analysis and knowledge mining
	MATS System modeling and simulation
	MATS Statistics and quantitative analysis

Skills area	Skills	Indicative content
Managerial skills	MANS Logistics and supply chain management	Controlling in Supply Chain Management
		Supply Chain and Sourcing
		Supply Chain Risk Management
		Mathematical models for Supply Chain Management
		Inventory Management
		Outsourcing (Make of Buy)
		e-logistics

Indicative content has also been assigned to each skill.

127 surveys among logistics companies located in Serbia, Slovenia, Croatia, and Poland

Criteria	Options	%
Sector of the company	Industry (operating with an integrated	36%
	Rail transportation	5%
	Road transportation	23%
	Air transportation	3%
	Maritime	4%
	Trade and service	36%
	Logistics service provider / 3PL /	16%
Company size	Under 25	23%
	26 - 50	6%
	51 - 250	21%
	251 – 500	17%
	More than 501	42%

Criteria	Options	%
Respondent's position	Managerial Staff	56%
	Technical Staff	13%
	Administrative Staff	16%
	Other	16%
Respondent's area of expertise	Engineering or other technical qualification	59%
	Other scientific	9%
	Law and Politics	2%
	Economics	18%
	Humanistic/Social	7%
	Other	9%

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Research Methodology

Correlation analysis of survey results

The correlation shows which competencies are similar to each other, i.e., which are the most **universal.**

The importance of competencies in business analytics

Survey results analysis in search of the relevance of competencies to business analytics **from the perspective of company managers** using the Ward's method.

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Research results

	MANS Quality and process management	MANS Data and knowledge management	MANS Logistics and supply chain management	MANS Strategic and economic analyses	MANS Basics of economics	MATS Optimization and Operational Research	MATS Decision and game theory	MATS AI & ML	MATS Data analysis and knowledge mining	MATS System modeling and simulation	MATS Statistics and quantitative analysis	AM&S Optimization in logistics	AM&S Data analysis and statistics	AM&S Visualization and reporting	IT Simulations	IT BI tools	IT Data analytics tools	IT Programming	IT Database	IT Visualisation	IT Management systems	IT Other IT tools
MANS Quality and process management	1																					
MANS Data and knowledge management	0,670	1																				
MANS Logistics and supply chain management	0,835	0,616	1																			
MANS Strategic and economic analyses	0,710	0,702	0,711	1																		
MANS Basics of economics	0,692	0,562	0,599	0,571	1																	
MATS Optimization and Operational Research	0,639	0,615	0,622	0,703	0,522	1																
MATS Decision and game theory	0,527	0,459	0,429	0,570	0,451	0,738	1															
MATS AI & ML	0,504	0,576	0,449	0,593	0,521	0,822	0,743	1														
MATS Data analysis and knowledge mining	0,643	0,630	0,566	0,703	0,540	0,887	0,779	0,835	1													
MATS System modeling and simulation	0,639	0,558	0,573	0,671	0,562	0,873	0,734	0,812	0,835	1												
MATS Statistics and quantitative analysis	0,635	0,610	0,590	0,695	0,536	0,846	0,628	0,775	0,853	0,795	1											
AM&S Optimization in logistics	0,687	0,511	0,649	0,646	0,569	0,735	0,635	0,661	0,765	0,690	0,705	1										
AM&S Data analysis and statistics	0,717	0,697	0,653	0,729	0,612	0,810	0,654	0,731	0,791	0,761	0,831	0,807	1									
AM&S Visualization and reporting	0,656	0,599	0,641	0,670	0,383	0,628	0,441	0,493	0,638	0,591	0,643	0,616	0,714	1								
IT Simulations	0,586	0,508	0,579	0,546	0,409	0,714	0,498	0,622	0,664	0,646	0,685	0,686	0,732	0,584	1							
IT BI tools	0,586	0,545	0,608	0,561	0,357	0,654	0,353	0,471	0,567	0,526	0,631	0,555	0,649	0,709	0,612	1						
IT Data analytics tools	0,527	0,540	0,475	0,561	0,401	0,757	0,584	0,710	0,747	0,693	0,680	0,710	0,702	0,628	0,710	0,637	1					
IT Programming	0,504	0,410	0,472	0,442	0,340	0,621	0,481	0,565	0,580	0,534	0,554	0,561	0,563	0,464	0,578	0,512	0,651	1				
IT Database	0,495	0,545	0,458	0,540	0,365	0,700	0,528	0,664	0,671	0,691	0,613	0,522	0,635	0,584	0,607	0,567	0,724	0,642	1			
IT Visualisation	0,405	0,373	0,433	0,430	0,242	0,538	0,381	0,487	0,557	0,478	0,530	0,592	0,539	0,511	0,581	0,504	0,682	0,507	0,554	1		
IT Management systems	0,563	0,395	0,557	0,475	0,316	0,444	0,208	0,258	0,377	0,361	0,424	0,515	0,527	0,531	0,458	0,658	0,422	0,361	0,437	0,464	1	
IT Other IT tools	0,560	0,536	0,547	0,474	0,405	0,533	0,407	0,550	0,531	0,460	0,526	0,586	0,587	0,494	0,623	0,540	0,585	0,616	0,552	0,489	0,464	1

- The analysis of the surveys shows that within the set of analysed competences there are some that correlate **strongly** with others;
- The **higher the value** in the matrix (the greener), **the more similar** the competencies are in terms of their importance for conducting business activities;
- Logistics companies have determined that **mathematical skills** are the most **universal** competencies;
- Having mathematical skills as **core competences** makes it easier to acquire other competences in the field of **business analytics**.

Source: Own elaboration

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Research results

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Small companies – less than 500 employees

	MANS Quality and process management	MANS Data and knowledge management	MANS Logistics and supply chain management	MANS Strategic and economic analyses	MANS Basics of economics	MATS Optimization and Operational Research	MATS Decision and game theory	MATS AI & ML	MATS Data analysis and knowledge mining	MATS System modeling and simulation	MATS Statistics and quantitative analysis	AM&S Optimization in logistics	AM&S Data analysis and statistics	AM&S Visualization and reporting	IT Simulations	IT BI tools	IT Data analytics tools	IT Programming	IT Database	IT Visualisation	IT Management systems	IT Other IT tools
MANS Quality and process management	1																					
MANS Data and knowledge management	0,729	1																				
MANS Logistics and supply chain management	0,868	0,611	1																			
MANS Strategic and economic analyses	0,746	0,715	0,685	1																		
MANS Basics of economics	0,759	0,547	0,624	0,592	1																	
MATS Optimization and Operational Research	0,660	0,653	0,612	0,704	0,534	1																
MATS Decision and game theory	0,567	0,560	0,466	0,637	0,475	0,832	1															
MATS AI & ML	0,582	0,652	0,480	0,600	0,574	0,856	0,828	1														
MATS Data analysis and knowledge mining	0,685	0,677	0,560	0,750	0,577	0,906	0,852	0,865	1													
MATS System modeling and simulation	0,632	0,616	0,559	0,651	0,570	0,864	0,772	0,858	0,824	1												
MATS Statistics and quantitative analysis	0,691	0,670	0,620	0,760	0,576	0,857	0,698	0,795	0,859	0,795	1											
AM&S Optimization in logistics	0,715	0,474	0,667	0,669	0,586	0,732	0,674	0,682	0,769	0,696	0,687	1										
AM&S Data analysis and statistics	0,764	0,740	0,680	0,785	0,593	0,836	0,731	0,777	0,813	0,797	0,868	0,792	1									
AM&S Visualization and reporting	0,714	0,696	0,654	0,744	0,516	0,668	0,594	0,569	0,688	0,619	0,694	0,634	0,786	1								
IT Simulations	0,623	0,567	0,599	0,584	0,471	0,734	0,588	0,683	0,666	0,636	0,674	0,687	0,770	0,538	1							
IT BI tools	0,649	0,583	0,605	0,594	0,416	0,673	0,493	0,536	0,590	0,522	0,642	0,565	0,702	0,724	0,622	1						
IT Data analytics tools	0,550	0,535	0,466	0,583	0,475	0,784	0,706	0,781	0,774	0,671	0,666	0,700	0,722	0,618	0,739	0,616	1					
IT Programming	0,527	0,482	0,503	0,458	0,377	0,675	0,527	0,600	0,613	0,579	0,541	0,569	0,571	0,460	0,649	0,508	0,702	1				
IT Database	0,527	0,625	0,446	0,584	0,462	0,740	0,659	0,693	0,693	0,714	0,610	0,488	0,651	0,549	0,595	0,527	0,720	0,601	1			
IT Visualisation	0,439	0,353	0,418	0,454	0,265	0,588	0,489	0,542	0,597	0,473	0,552	0,611	0,552	0,439	0,619	0,417	0,638	0,583	0,443	1		
IT Management systems	0,625	0,362	0,560	0,476	0,348	0,377	0,203	0,236	0,333	0,298	0,386	0,501	0,530	0,444	0,387	0,598	0,287	0,307	0,317	0,280	1	
IT Other IT tools	0,652	0,573	0,627	0,518	0,524	0,510	0,462	0,523	0,500	0,504	0,432	0,581	0,620	0,465	0,668	0,498	0,581	0,623	0,483	0,466	0,401	1

In the correlation analysis, **small companies** indicate **mathematical skills** as the most universal.

In the correlation analysis, **big companies** indicate **applied math & stat, and IT skills** as the most universal.

Big companies – 500+ employees

	MANS Quality and process management	MANS Data and knowledge management	MANS Logistics and supply chain management	MANS Strategic and economic analyses	MANS Basics of economics	MATS Optimization and Operational Research	MATS Decision and game theory	MATS AI & ML	MATS Data analysis and knowledge mining	MATS System modeling and simulation	MATS Statistics and quantitative analysis	AM&S Optimization in logistics	AM&S Data analysis and statistics	AM&S Visualization and reporting	IT Simulations	IT BI tools	IT Data analytics tools	IT Programming	IT Database	IT Visualisation	IT Management systems	IT Other IT tools
MANS Quality and process management	1																					
MANS Data and knowledge management	0,537	1																				
MANS Logistics and supply chain management	0,763	0,629	1																			
MANS Strategic and economic analyses	0,619	0,674	0,784	1																		
MANS Basics of economics	0,556	0,608	0,581	0,538	1																	
MATS Optimization and Operational Research	0,585	0,528	0,644	0,699	0,514	1																
MATS Decision and game theory	0,455	0,273	0,355	0,445	0,426	0,565	1															
MATS AI & ML	0,309	0,394	0,361	0,574	0,406	0,738	0,590	1														
MATS Data analysis and knowledge mining	0,539	0,519	0,563	0,578	0,490	0,843	0,645	0,768	1													
MATS System modeling and simulation	0,435	0,293	0,454	0,523	0,391	0,770	0,511	0,653	0,692	1												
MATS Statistics and quantitative analysis	0,506	0,479	0,529	0,540	0,453	0,823	0,506	0,728	0,863	0,715	1											
AM&S Optimization in logistics	0,619	0,595	0,610	0,589	0,539	0,741	0,569	0,607	0,762	0,567	0,747	1										
AM&S Data analysis and statistics	0,614	0,605	0,610	0,595	0,654	0,759	0,524	0,624	0,761	0,582	0,748	0,846	1									
AM&S Visualization and reporting	0,540	0,403	0,596	0,512	0,155	0,544	0,160	0,326	0,507	0,391	0,555	0,594	0,614	1								
IT Simulations	0,509	0,388	0,548	0,463	0,285	0,676	0,344	0,488	0,671	0,561	0,707	0,686	0,622	0,638	1							
IT BI tools	0,497	0,495	0,639	0,528	0,288	0,642	0,155	0,376	0,545	0,411	0,632	0,558	0,511	0,712	0,611	1						
IT Data analytics tools	0,469	0,547	0,483	0,499	0,254	0,689	0,347	0,530	0,672	0,604	0,720	0,737	0,639	0,665	0,653	0,692	1					
IT Programming	0,499	0,319	0,478	0,451	0,280	0,574	0,436	0,548	0,579	0,459	0,599	0,579	0,511	0,599	0,488	0,534	0,620	1				
IT Database	0,418	0,370	0,475	0,437	0,178	0,609	0,288	0,582	0,604	0,572	0,623	0,600	0,639	0,639	0,633	0,640	0,728	0,749	1			
IT Visualisation	0,351	0,410	0,449	0,403	0,253	0,461	0,212	0,404	0,482	0,437	0,522	0,583	0,553	0,559	0,546	0,611	0,777	0,464	0,740	1		
IT Management systems	0,476	0,455	0,571	0,497	0,290	0,566	0,208	0,306	0,462	0,382	0,493	0,558	0,559	0,691	0,579	0,726	0,663	0,444	0,629	0,690	1	
IT Other IT tools	0,437	0,497	0,447	0,430	0,245	0,578	0,337	0,630	0,607	0,380	0,693	0,677	0,647	0,697	0,574	0,668	0,621	0,619	0,675	0,524	0,535	1

Source: Own elaboration

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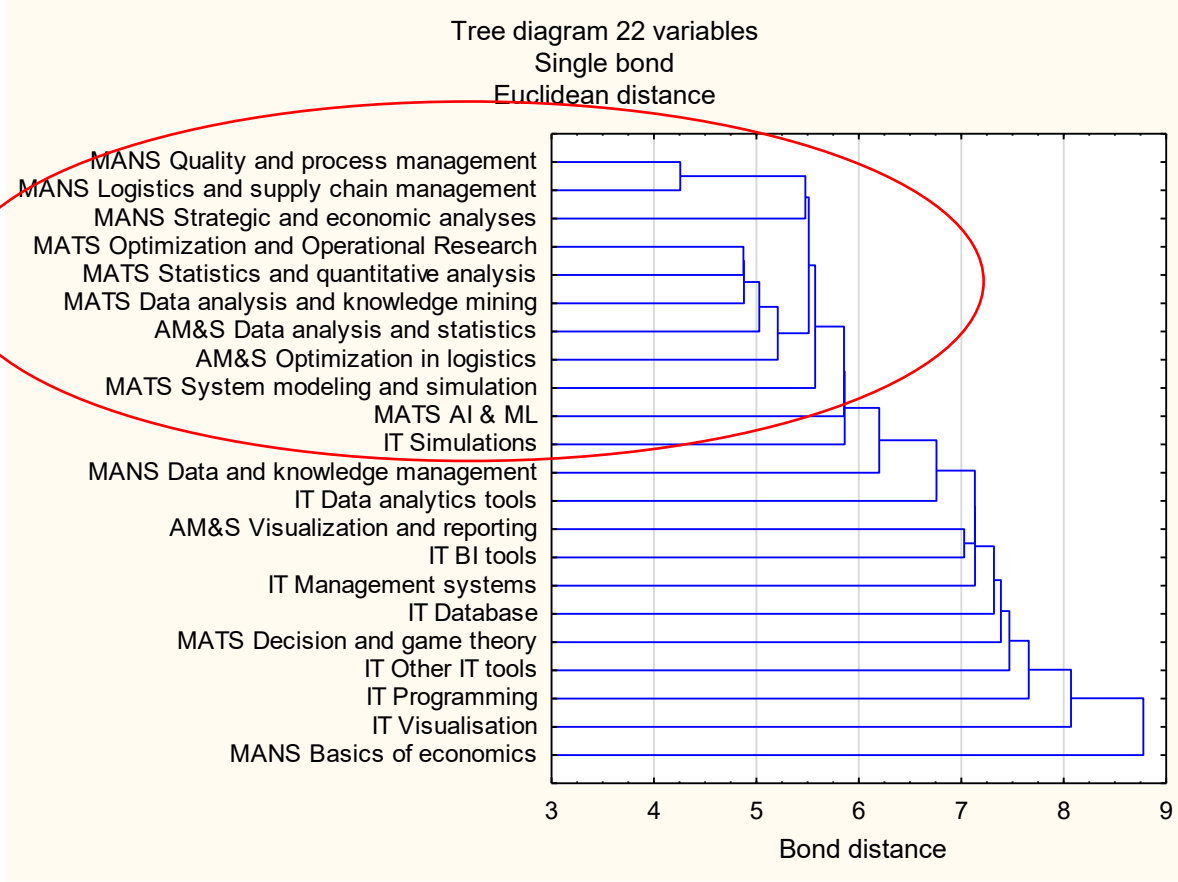
Research results



All companies

- Cluster analysis conducted using **Ward's method** indicates that the smaller the binding distance between competencies, the greater the correlation between them.
- The analysis shows that **managerial skills** are the most important for business managers in terms of business analytics.

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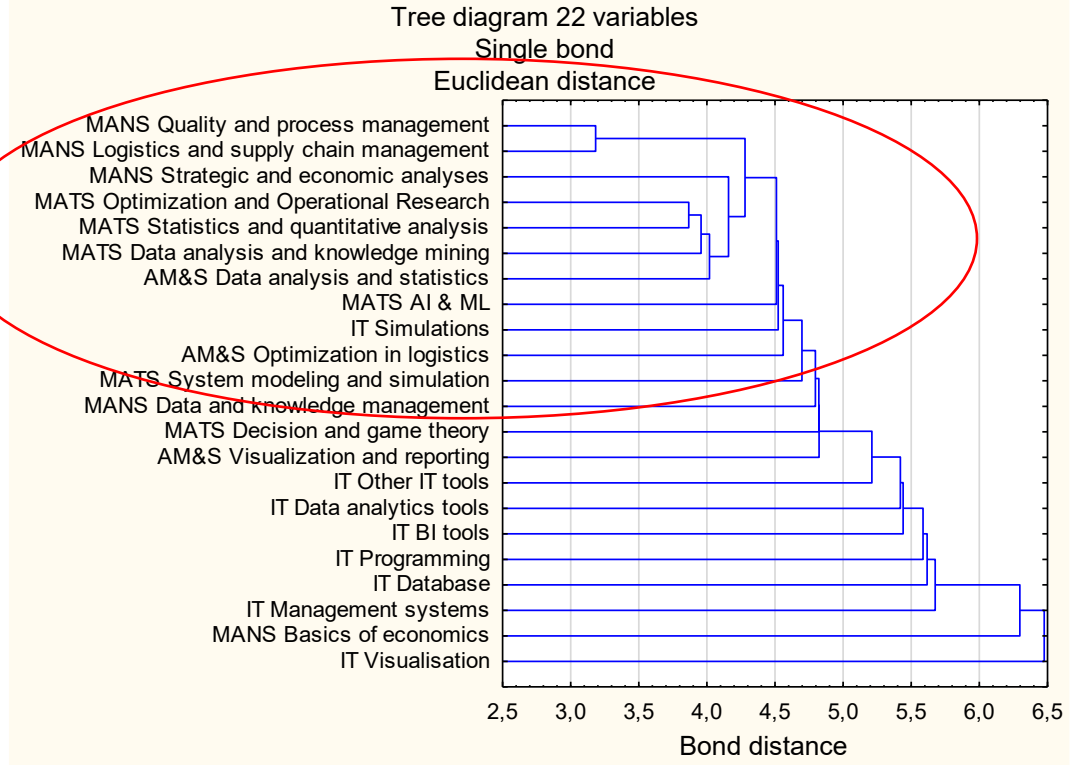
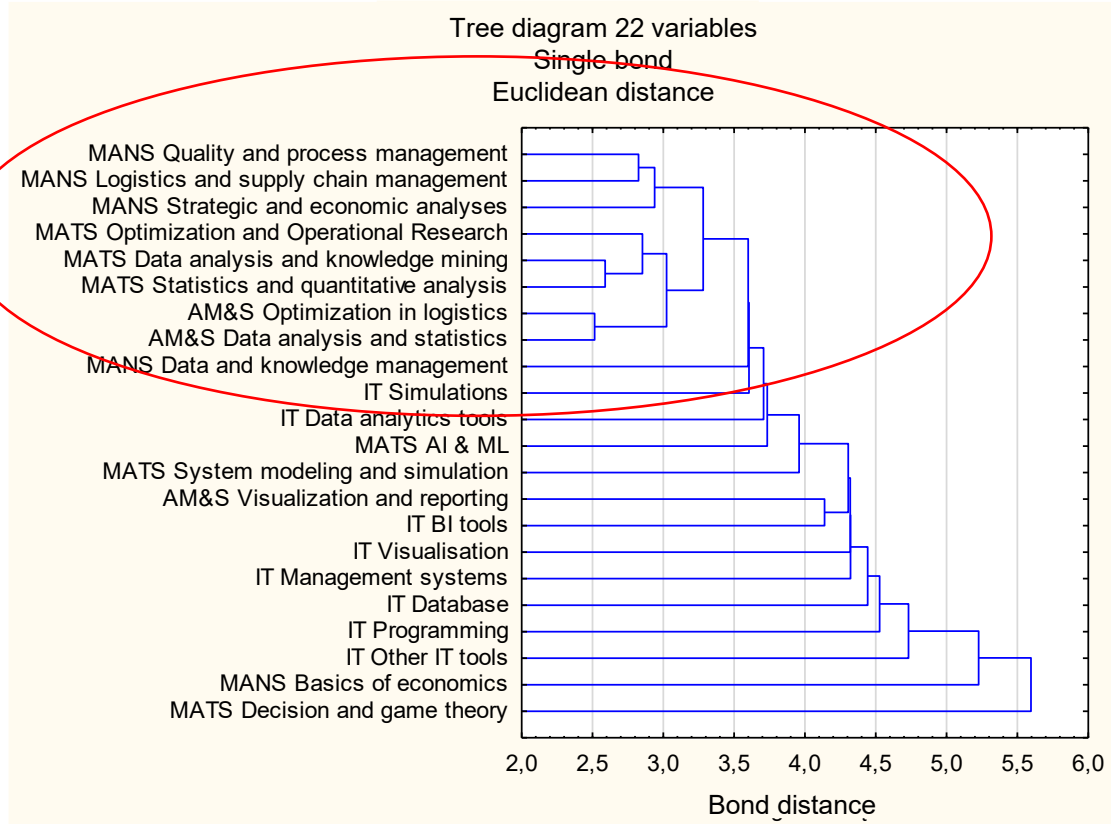
Research results

Small companies – less than 500 employees



Big companies – 500+ employees



There are **no significant differences** in how managers of large and small companies perceive these competencies.

Source: Own elaboration

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Conslusions

- The role of education is to develop universal competences – **mathematical skills (theoretical) aspects and applied math & stat**;
- **Managerial skills** in business analytics are more important from the point of view of companies;
- As part of their managerial skills, students should acquire **competences** in the use of logistics process management methods and logistics system design, while **experience** is a matter of practical development through employment in logistics companies;
- The **curricula at Polish universities** should be supplemented with the conclusions drawn from this research.

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Improving Supply Chain Analytics Skills at EFOS through BAS4SC Project

Davor Dujak
Dario Šebalj
Jelena Franjković
Josip Juraj

BAS4SC

Business Analytics Skills
for the Future-proof Supply Chains

Project number – 2022-1-PL01-KA220-HED-000088856

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Strong tradition in economics and business education (from 1961)

ELA certified SCM and logistics materprogram

Active in international projects and Erasmus+ programmes

Long cooperation with Poznan School of Logistics

Business Analytics Skills for Future-proof Supply Chain (BAS4SC)

Erasmus+ KA2 project

duration: 3 years

Aim: *to develop business analytics skills for resilient supply chains*

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team members contributed as:

- Authors & editors
- Translators & reviewers
- Trainers & disseminators

Assist.Prof.
Jelena Franjković

Assist.Prof.
Ana Živković

Assist.Prof.
Dario Šebalj

Prof.
Davor Dujak

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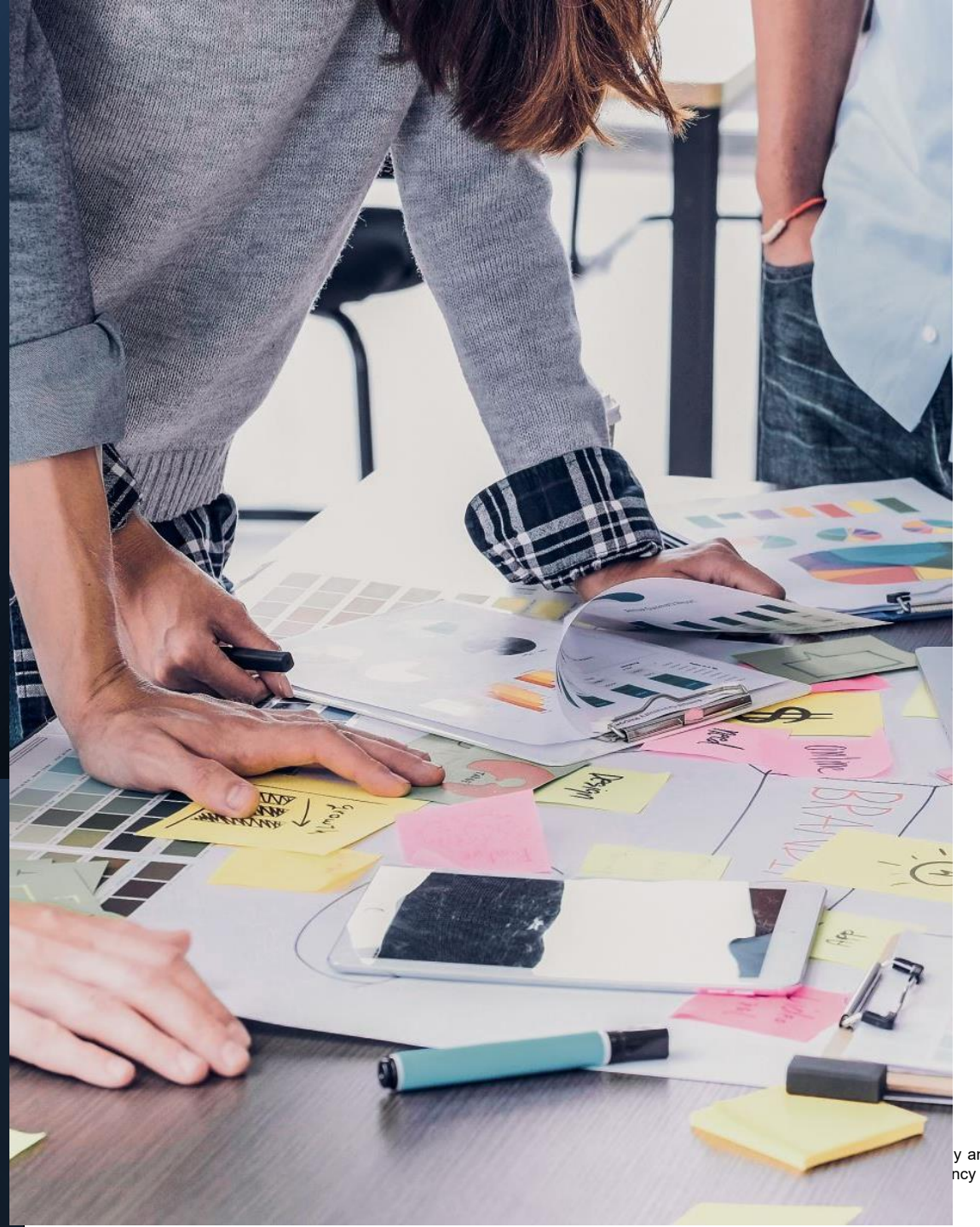
Our **goals** were:

- Develop teaching materials on Business Analytics & Supply Chain
- Provide practical training with tools (e.g., Tableau)
- Support integration into higher education curriculum
- Strengthen international collaboration



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ncy (NA).

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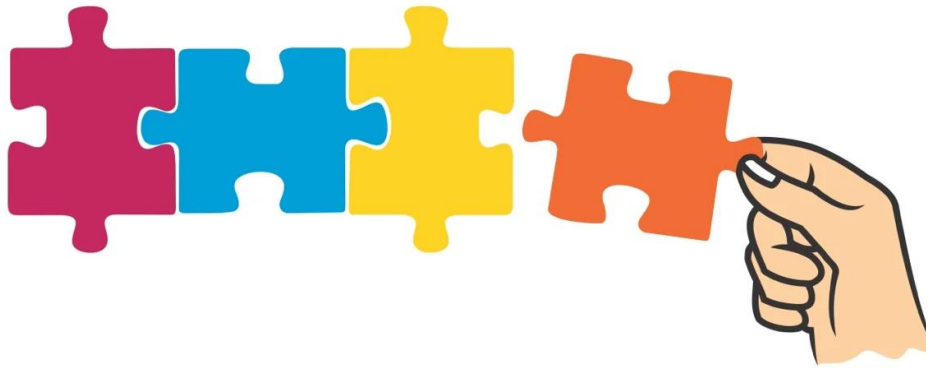
EFOS **contributions** included:

- Writing Book C2 (*Business Intelligence*)
- Translation/adaptation of all books (C1, C2, C3)
- Development of Tableau exercises
- Testing meetings & piloting with students
- Dissemination through events, papers, media



BUSINESS ANALYTICS SKILLS FOR THE FUTURE-PROOFS SUPPLY CHAINS -

BUSINESS INTELLIGENCE

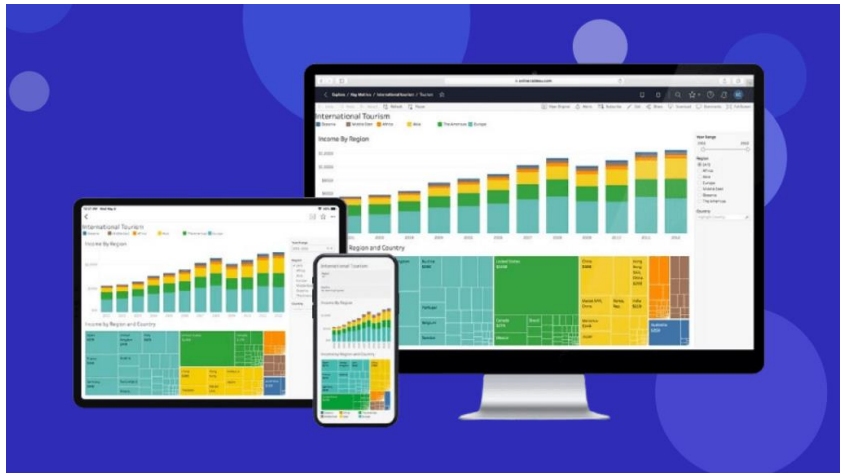
Authors:
Dario Šebalj
Dejan Mirčetić
Michał Adamczak

Co-funded by the European Union

- EFOS contributed to writting, translation & editing
- Ensured accessibility of materials in Croatian language
- Enhanced quality and alignment of teaching resources

Co-funded by the European Union

- EFOS prepared exercises in Tableau
- Focus on data visualization and analytics
- Used in student training and testing



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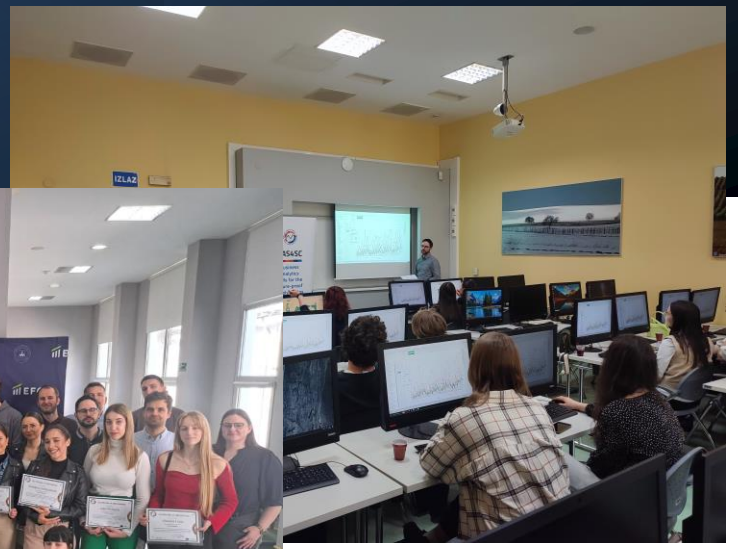
- EFOS hosted 2 and participated in 4 Testing Meetings

- Piloting with Croatian students ensured feedback on materials



Strong Dissemination activities

2 international multiplier events organized (< 60 people from academia and practice)
1 international conference presentation
2 scientific papers published
Wide media and social networks outreach over 3 years

Results:

- BAS4SC content integrated into EFOS Master's program (Business Economy, direction SCM and Business Informatics)
- **6** courses at EFOS **updated** with BAS4SC project outputs
- Ensured long-term sustainability

Results:

- Improved teaching resources and student skills
- Strengthened international collaboration – both for students and professors
- Enhanced visibility of EFOS in Erasmus+ projects

Future perspectives:

- Continuing integration of (not only) business analytics into supply chain courses
- Building on BAS4SC results for new projects

Thank you!

davor.dujak@efos.hr

EFOS

Faculty of Economics and Business in Osijek

Business Analytics Skills for the Future-proof Supply Chains

Knowledge-Based Engineering in Strategic Logistics Planning: From Ontology to BAS4SC Insights

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Business Analytics Skills
for the Future-proof Supply Chains

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Agenda

- Motivation
- Research aim
- Research placement
- Conceptual foundations
- LKMS architecture
- Methods & Lifecycle
- Results
- Benefits of LKMS
- Conclusions & Future outlook

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Motivation

- Push towards incorporating sustainable appraoches in logistics and supply chains;
- Need for robust strategic planning frameworks;
- Challenges related to fragmented data, lack of formal semantics as support;
- Rising risks due to interoperability across organizations.

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Research aim

- The aim was to develop a Logistics Knowledge Management System (LKMS)
- Build on Design for Six Sigma (DFSS) business improvement experiences
- Test if knowledge-based engineering (KBE) is:
  - More efficient,
  - More adaptable &
  - More sustainable.

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Research placement

- To establish concurrent research development a literature review was conducted;
- Search of scientific papers in Scopus and Web of Science databases between the year 2019 and 2024;
- A dataset of 242 relevant scientific papers was analyzed with Leximancer software.

Database	Search query	No. of hits	1st screening	2nd screening
Scopus	"ontology" AND "six sigma" AND "knowledge base"	59	49	35
Scopus	"ontology" AND "six sigma" AND "knowledge-based engineering"	11	9	7
Scopus	"ontology" AND "Knowledge base" AND "engineering"	8443	4738	171
WoS	"ontology" AND "six sigma" AND "knowledge base"	3	1	1
WoS	"ontology" AND "six sigma" AND "knowledge-based engineering"	1	1	1
WoS	"ontology" AND "Knowledge base" AND "engineering"	1457	649	74

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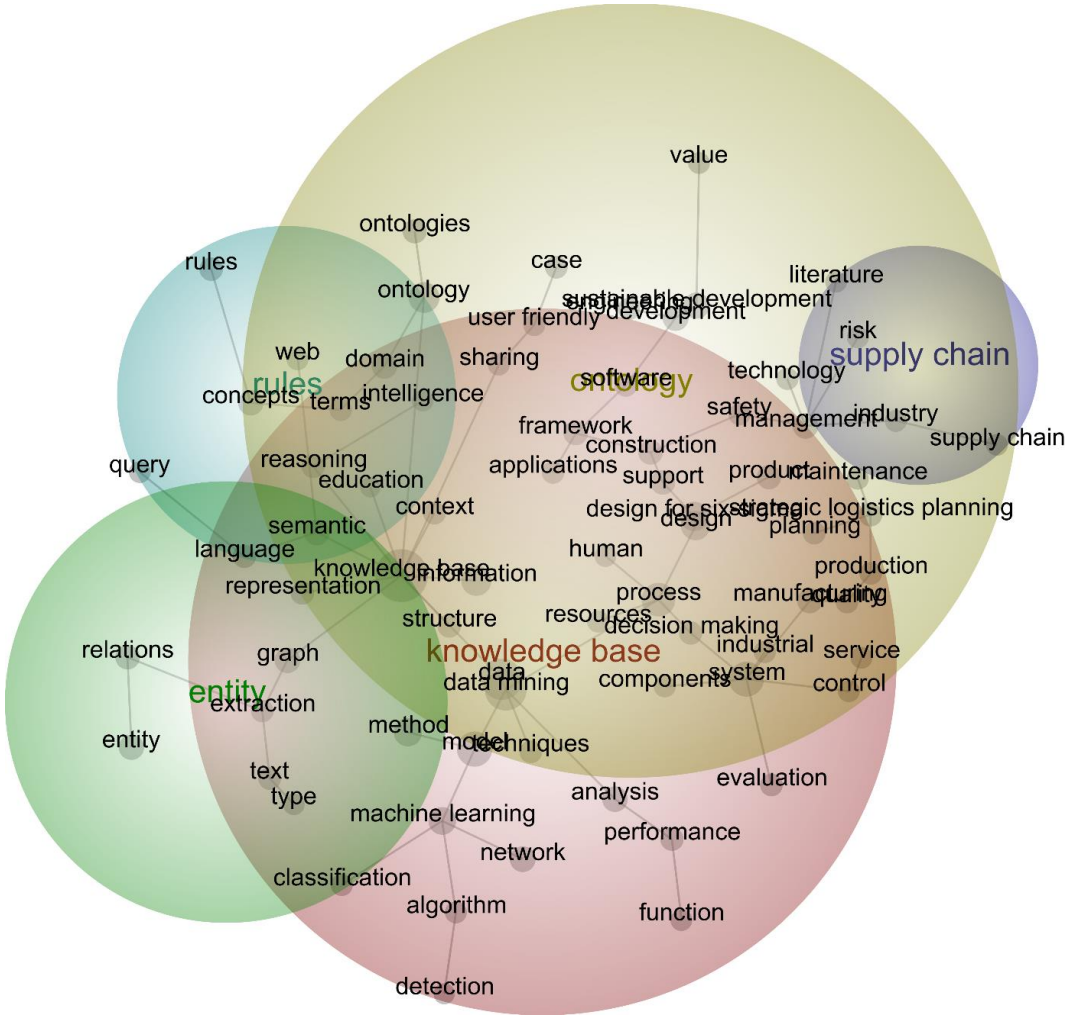
Research placement

- The results identified five main themes:
  - Knowledge base,
  - Ontology,
  - Entity,
  - Rules,
  - Supply chain.
- The identified gap indicated that there is currently a limited focus on integration of ontology and KBE in logistics & supply chain



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Conceptual foundations

- Based on the results a combination of three foundations was considered for the future model:
  - Ontology: structured semantics, knowledge sharing
  - KBE: embeds knowledge into engineering workflows
  - DFSS: systematic improvement (Define → Verify)
- The snipet of the final cycle of the conceptual foundations is visible on the right side.

DFSS SCM Experiences Catalog

```
**************************************************
*****************
Phase: Define, Measure, Analyze, Design, Verify
Scope: strategic, tactical or operational
Type: network design, strategy formulation, opera
tions planning
Focus: capacity planning, performance monitoring,
 quality assurance
**************************************************
*****************
Phase1 (Define)
!------------ Strategic -------------!
1. Conceptual modeling
1.1 Mind charts
1.2 Organizational charts
1.3 Process diagrams
!------------ Tactical -------------!
2. Logical modeling
```

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LKMS architecture

- The architecture of the LKMS was structured as following:
  - Ontology-based knowledge base: entities, attributes, relations
  - Tools: Protege, Fluent Editor, Apache Jena (semantic web)
  - Supports OLAP queries, integration with BI/BA tools
  - Human-readable via English Controlled Natural Language (ECNL).
- The final architecture is visible on Figure 2.

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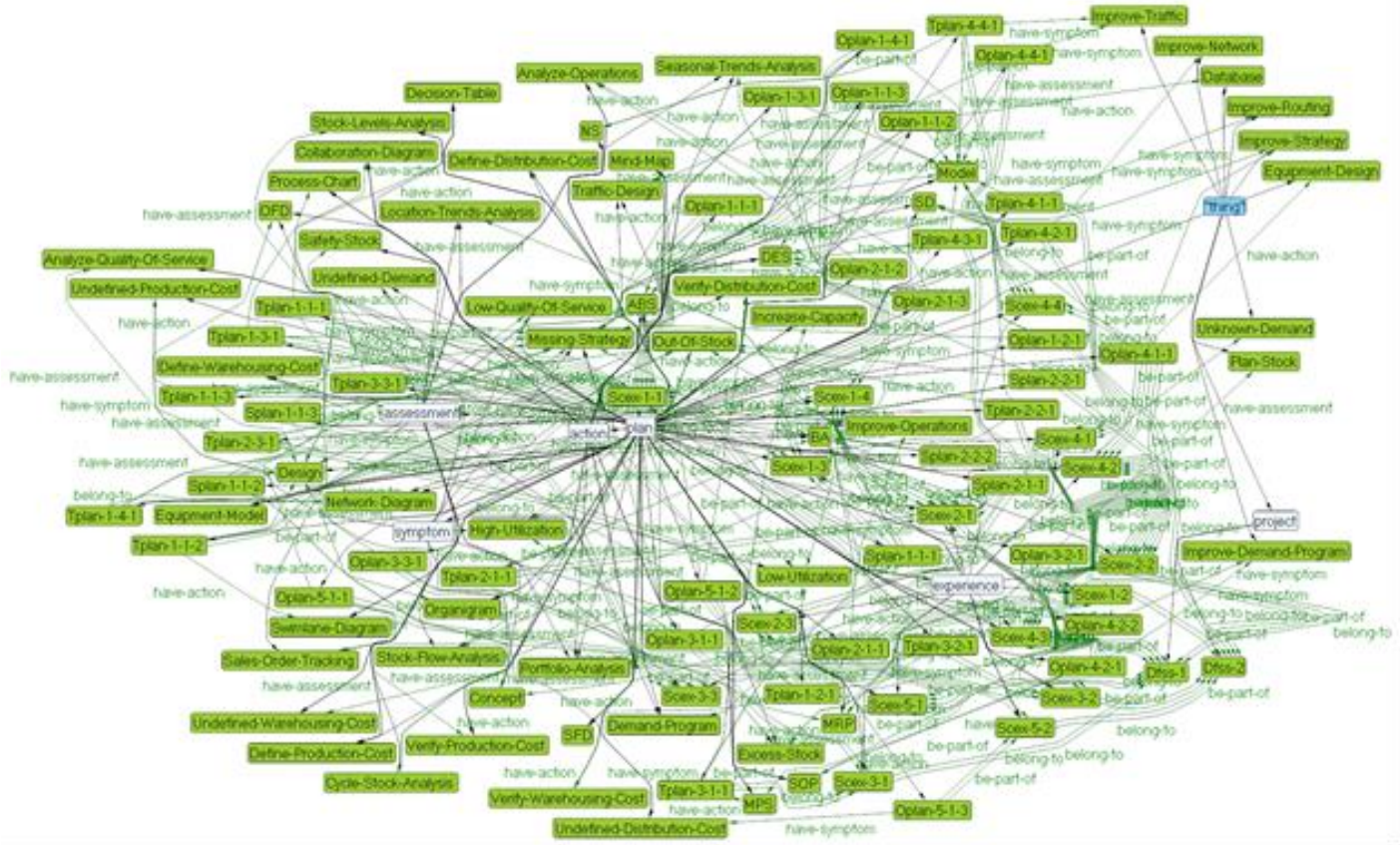
LKMS architecture figure



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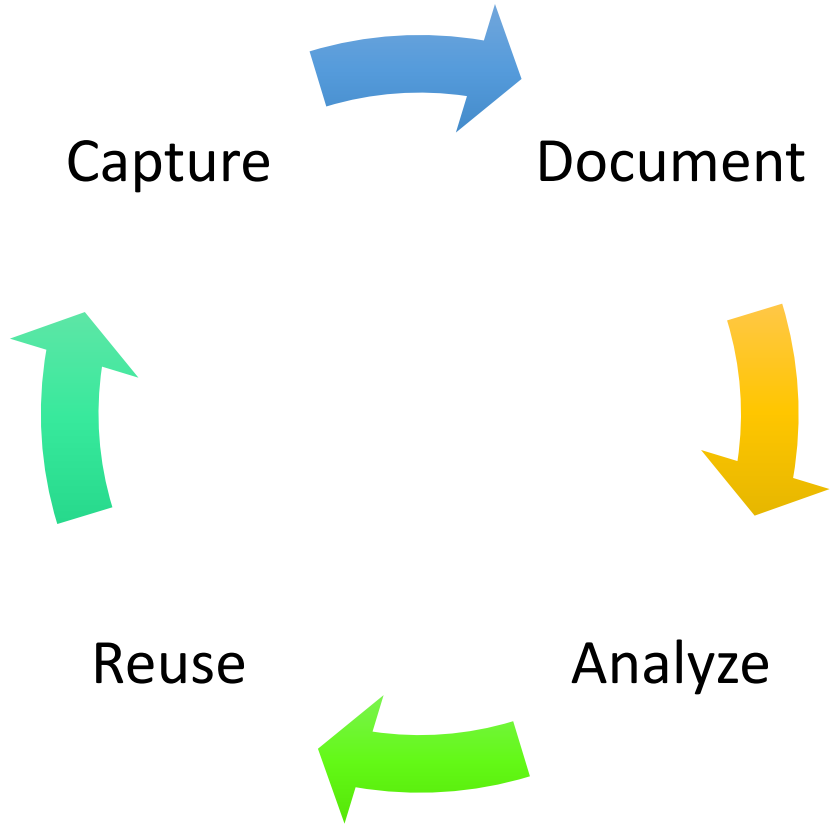
Methods & Lifecycle

- The knowledge lifecycle steps considered followed a circular and repetitive approach;
- The concept integrates methods of CAD/CAM, simulation, ERP and BI;
- Anchored in DFSS and OPDSA, which embeds continuous improvement in planning.



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Results

- A case study was conducted to test the conceptual foundation;
- A student-assisted project with industry partner was considered;
- The problem was a perceived need for a second production line;
- LKMS revealed poor utilization of existing line
- DFSS phases applied: Define, Monitor, Analyze, Design, Verify
- The outcome was an optimized production without costly expansion

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Results table

Dfss-1	Phase	Scope	Type	Focus
Scex-1-1	define	strategic, tactical, operational	strategy-formulation, operations-planning	capacity-planning
Scex-2-1	monitor	strategic, tactical, operational	strategy-formulation, operations-planning	performance-monitoring, capacity-planning
Scex-3-1	analyze	tactical, operational	operations-planning	performance-monitoring, capacity-planning
Scex-4-1	design	tactical, operational	operations-planning	capacity-planning
Scex-5-1	verify	operational	operations-planning	performance-monitoring

Scex-1-1 defines the system model with its key components and processes on the strategic, tactical and operational levels, thus making it manageable. Various design methods (mind-maps, organigrams, process-charts, decision-tables, swimlane diagrams, object-flow diagrams, equipment, data and service models) have been applied to formalize conceptual and logical models of the company. Based on these insights students could grasp the physical production process characteristics and the environmental conditions in which the company operates.

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Benefits of LKMS

- The benefits of the LKMS identified in the research were as follows:
- Structured, context-aware knowledge base;
- Speeds up decision-making;
- Integrates sustainability into planning;
- Scales without clutter — knowledge grows organically.

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Educational impact and integration

- LKMS can be effectivelly integrated into educational processes;
- Active implementation during logistics courses and final thesis works at Faculty of Logistics University of Maribor;
- Students get familiar and trained on how to model conceptual → logical → physical models;
- The LKMS helps to manage complexity and provides insight to „see the big picture", within existing or conceptual organisations;
- Supports all three BAS4SC modules.

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Conclusion & Future Outlook

- Ontological knowledge bases are efficient, adaptable and support sustainable approaches;
- LKMS expert system tested in the research confirmed as valid proof-of-concept;
- The following steps are aimed to:
  - Provide empirical validation with broader datasets;
  - Benchmarking against other existing KM tools;
  - Integration with AI-driven predictive analytics.

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Machine learning in Business Intelligence

Dejan Mircetic
Marinko Maslaric
Sanja Bojic

BAS4SC

Business Analytics Skills
for the Future-proof Supply Chains

Project number – 2022-1-PL01-KA220-HED-000088856

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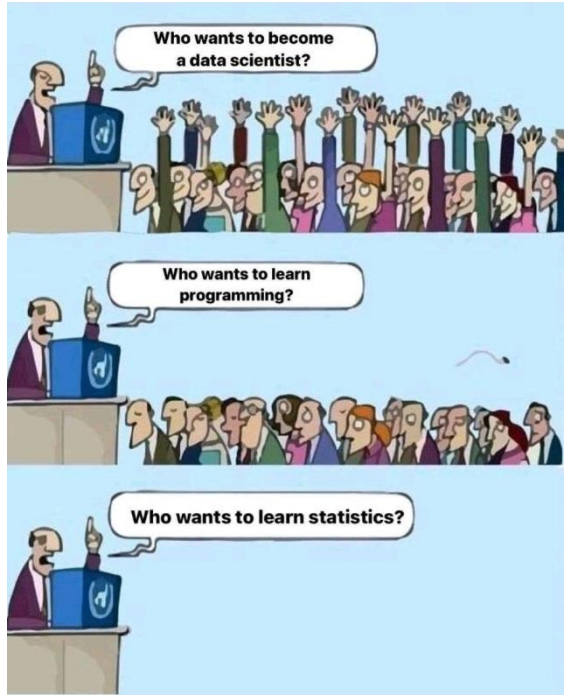
Business Analytics key pillars

- **AIMS & PURPOSE**
  - Business Data Analytics (BDA) represents a holistic approach of analysing data and making business decisions. It is a data and business driven environment with aim of boosting companies business performance by providing foundations for enhanced decision making.
  - BA provides a coherent connection between raw data and business decisions.
- **TECHNOLOGY BACKGROUND**
  - BDA has a strong background in various mathematically driven approaches. The backbone of BA is in: statistical theory, operation research, predictive analytics, artificial intelligence, programming, deep learning, and etc.
- **END USERS DOMAIN**
  - Supply Chain Analytics, Financial Analytics, Web Analytics, Google Analytics, Software Analytics, Crisis Analytics, Knowledge Analytics, Marketing Analytics, Customer Analytics, Service Analytics, Human Resource Analytics, Talent Analytics, Process Analytics, Risk Analytics, etc.



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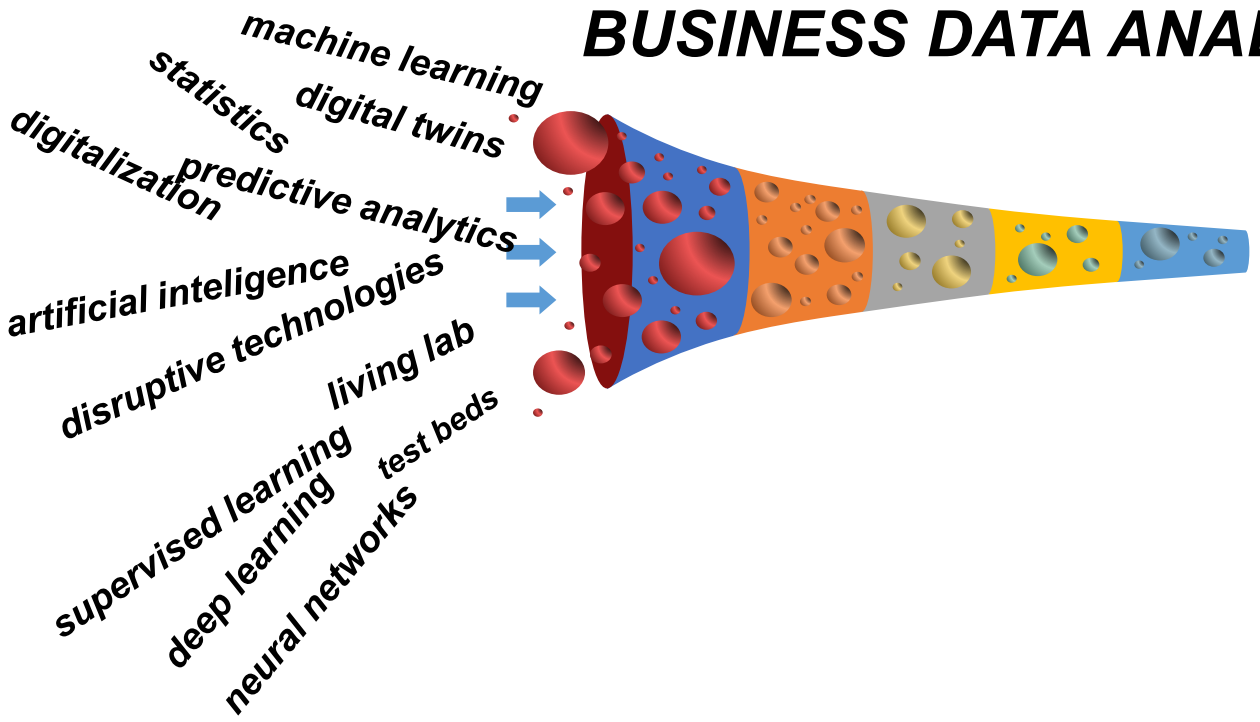
Rationale for analytics

Trends, Tools & Benefits

BUSINESS DATA ANALYTICS



- *Achieve a competitive advantage*
- *Support of an organization's strategic and tactical goals*
- *Better organizational performance*
- *Better decision outcomes*
- *Better or more informed decision processes*
- *Knowledge production*
- *Obtaining value from data*

Maximising business value

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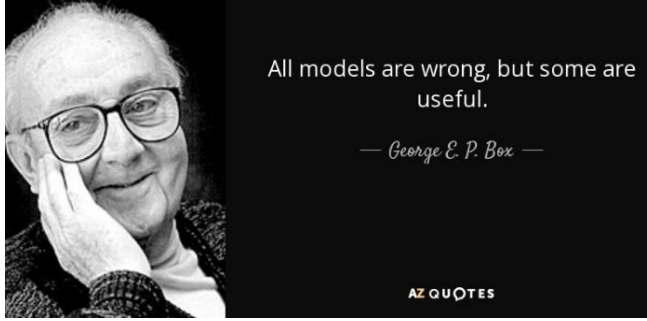
Enhanced Decision Making



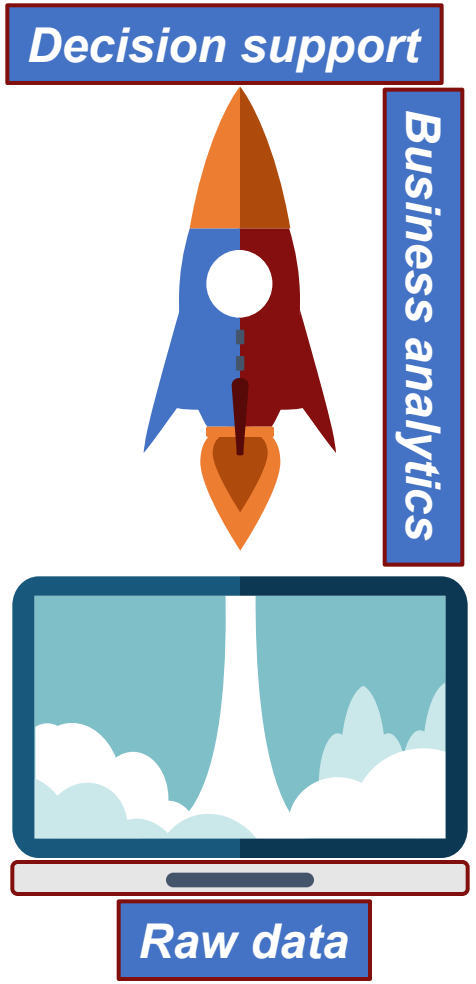
- At its core, BDA is about leveraging value from data, where data has recently been deemed 'the new oil.'

- Transforming data in business usable knowledge. Not the case in many practical applications (to model-centric and mathematically centric, requires deep expertise in mathematics, metrics not aligned with business utility).

"All models are wrong but some are useful!" George Box

"Don't fall in love in your models!" Foresight journal

- In practice BDA is usually derived to the final users in a form of decision support systems (DSS), expert systems (ES), forecasting support systems (FSS), upcoming in nearby future: automated artificial intelligence (AI) BDA systems!



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Trends in Industry & Education

- In the past few years, the BDA is becoming increasingly popular in the industry. Industry recognized the added value which can BA bring.
- Examples:

FedEx

Microsoft

3PL
Third Party Logistics
WE DRIVE YOUR LOGISTICS

- **Response of education:**
  - "Interdisciplinary approach for enhancing knowledge in supply chain analytics (SCAN)"
  - 15 different Universities in 10 central European countries. Joint PhD study program in supply chain analytics.

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What is machine learning?

- Machine learning is a subset of artificial intelligence (AI) that involves the development of algorithms and statistical models that enable computers to perform tasks without being explicitly programmed for those tasks. The primary goal of machine learning is to enable computers to learn from data and improve their performance over time without human intervention.

- ML arises from this question: could a computer go beyond "what we know how to order it to perform" and learn on its own how to perform a specified task? Could a computer surprise us? Rather than programmers crafting data-processing rules by hand, could a computer automatically learn these rules by looking at data?

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What is machine learning?

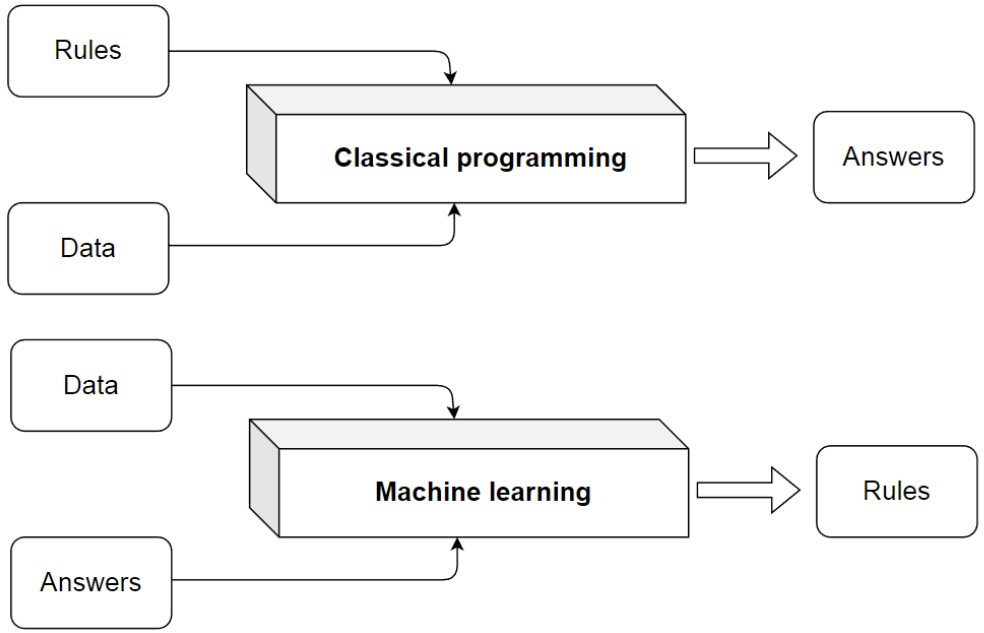

Figure. The classical programing vs. machine learning system training (Chollet, 2021).

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Foundations and theoretical assumptions of ML

- Machine learning's integration into business intelligence (BI) has transformed decision-making.
- ML rooted in mathematics, especially statistics.
- Ongoing debate: Is ML its field or part of statistics?
- ML algorithms often operate beyond traditional mathematical boundaries.
- ML vital in BI for data preprocessing, mining, and applying insights.
- ML enhances decision-making in organizations.
- Integration of ML into BI workflows for actionable insights.
- Bridging mathematics and practice in ML for effective BI.
- Strategies for optimizing ML algorithms for real-world BI applications.
- Importance of using ML outputs in decision-making.

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Business intelligence and ML in SCs

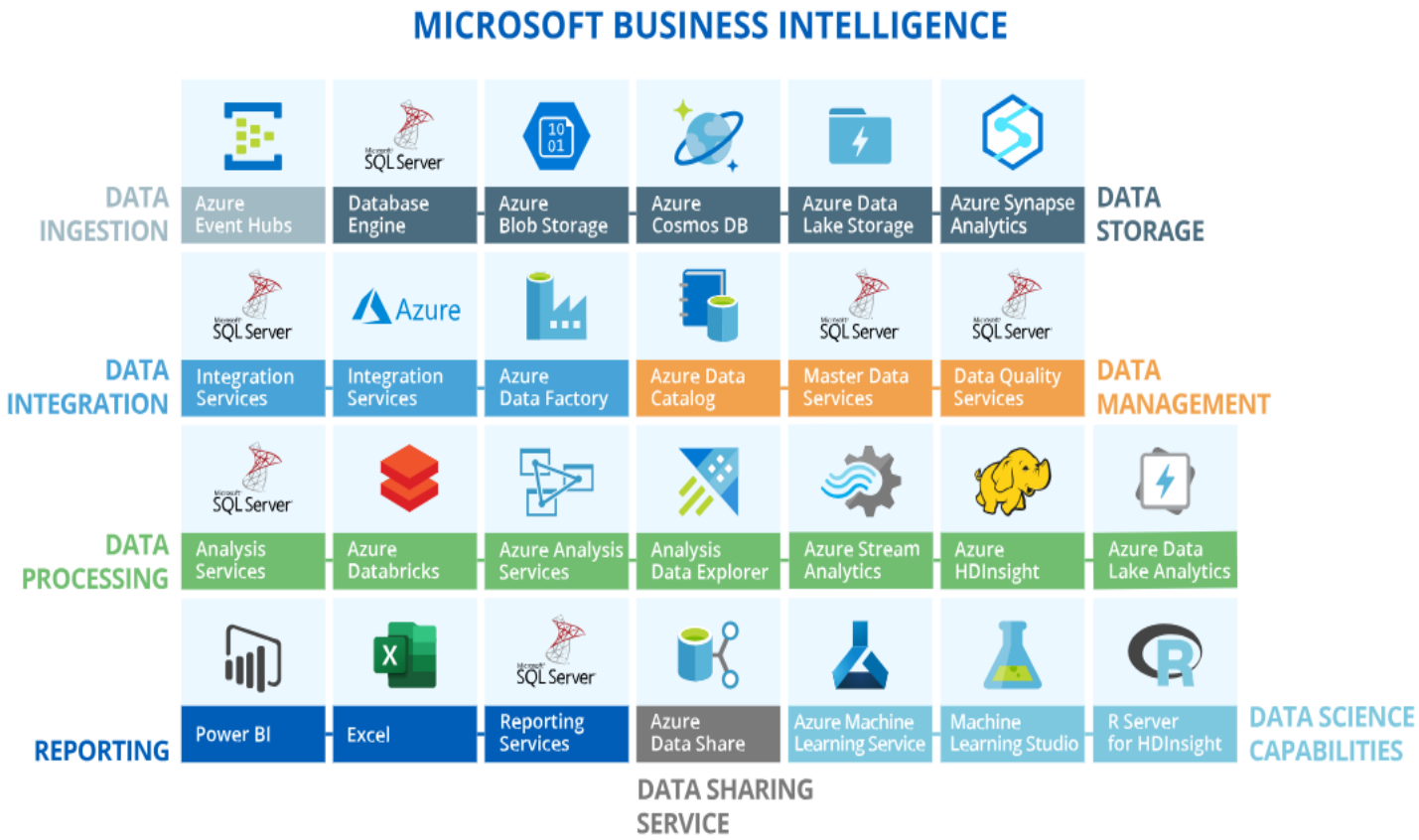

Figure. Microsoft business intelligence architecture.

Figure was addpted from https://www.scnsoft.com/services/business-intelligence/microsoft

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Business intelligence and ML in SCs

- Business intelligence (BI) in SCs involves drawing conclusions about observed processes based on data modeling.
- Incorporation of Mathematics: BI relies heavily on statistics but also utilizes operations research, linear algebra, fuzzy logic, numerical optimization, metaheuristics, etc.
- Emerging Technologies: New disruptive technologies such as machine learning, artificial intelligence, digital twins, smartization, living labs, etc., are gaining importance in data analysis and conclusions delivery.
- Lack of Strict Procedures: BI and ML workflows lack strict organization but rely on successful guidelines from practice and literature.
- Diverse Procedures: BI procedures vary based on the software used. For instance, Microsoft's Business Intelligence package offers tools for data ingestion, storage, integration, management, processing, reporting, sharing, and data science.
- Tools Offered: Microsoft's BI package provides tools for different tasks, including data ingestion, storage, integration, management, processing, reporting, sharing, and data science.

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Business intelligence and ML in SCs

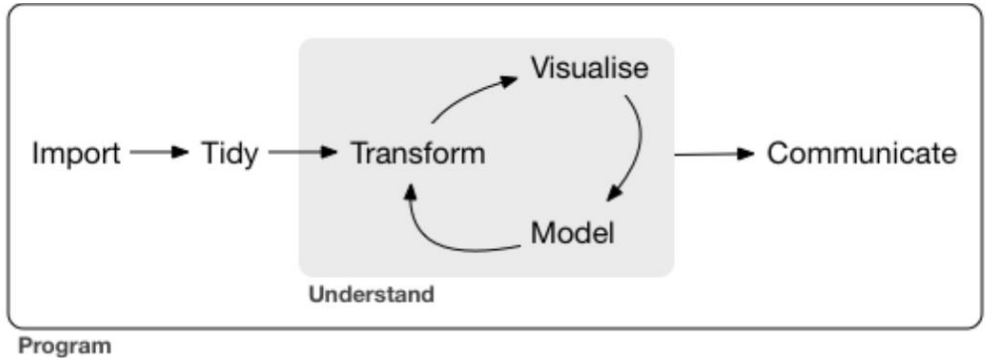

Figure. ML Data analysis steps in R, Wickham et al. (2023).

- ML procedures are primarily applied at the data science level using tools like Azure ML services, ML Studio, and R Server for HDInsight.
- Misconception: There's a common misconception that building ML algorithms consumes the majority of time and effort.
- Reality Check: In reality, most time is spent on data wrangling and preprocessing tasks, rather than the modeling process.
- Complementary Roles: Visualization and modeling serve distinct but complementary roles in data analysis.

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Business intelligence and ML in SCs

- Visualization: Offers insights that may elude formalized approaches and prompts new inquiries.
- Modeling: Provides a mathematical framework for answering precisely formulated questions and handling large datasets.
- Synergy: The synergy between visualization and modeling enhances the data analysis process, leading to more comprehensive insights.
- Vital Step: Communication is crucial for the success of data analysis.
- Decision Making: Providing information to decision-makers in a clear and consistent manner is essential.
- Ensuring Value: Effective communication ensures that the insights derived from data analysis contribute to informed decision-making and organizational success.

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