FBD_BMODEL

FASHION BIG DATA BUSINESS MODEL

D7.2

Business Pilot Benchmarking

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RE	Restricted to a group specified by the consortium (incl. Commission Services)	
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1 Executive Summary

Business pilot benchmarking deliverable, D7.2, it is presenting the benchmarking and validation of the FBD_BModel data services.

Within the framework of the EU H2020 funded project FBD_BModel (https://www.fbd-bmodel.eu/), data services and a technology platform to support the digitalization of design and production of localised small series of functional garments have been developed and implemented for a benchmarking and a piloting validation.

7 Cloud-based Data Services in the CC_IDS (**Cloud Computational Integrated Design System**):

- HUMAN BODY CLASSIFICATION (1)
- CONSUMER PROFILING (2)
- FASHION & FUNCTIONAL DESIGN RECOMMENDATIONS (to consumer - 3 & 4)
- FASHION & FUNCTIONAL FITTING EVALUATIONS (on the product - 5)
- KNOWLEDGE BASE CREATION & ADJUSTMENT (6)
- FABRIC & GARMENT DIGITALIZATION (7)

7 Cloud-based Data Services in the SCPMS (**Supply Chain & Production Management System**):

- SUPPLIERS SELECTION (1)
- MATERIAL & PRODUCT TESTING & CERTIFYING (2)
- CLOUD DATABASES & SERVICES FOR CERTIFIED TEXTILE & APPAREL MANUFACTURERS (3)
- PRODUCTION SIMULATION & OPTIMISATION (4 & 5)
- INTEGRATION OF ENVIRONMENTAL FOOTPRINT ASSESSMENT (static service - 6)
- ONLINE PRICING, TRADING & FINANCIAL TRANSACTION SERVICE (not implemented)
- CREATION, MANAGEMENT & UPDATING OF THE PRODUCTION KNOWLEDGE BASE (7)

The product design and production, in terms of materials and supply chain, for the demonstration products, have been tested using the IT-based tools and services deployed in the FBD_BModel technology platform.

Together with these data services, a Business Model & singular Business Plans, for the 4 business use-cases used for trialling the FBD technology platform, have also been released (for more details, see the deliverable D7.5).

The following deliverable it is so structured:

- After a summary introduction of the overall FBD_BModel framework, in terms of the data services developed, the business use cases with which the trialling/piloting has been done are presented.
- The following 3 sections cover the core part of the deliverable, specifically the benchmarking and validation divided for:
  - The **FBD Functional CC_IDS data services** (with the interconnections with the SCPMS data services).
  - The **FBD Fashion CC_IDS data services** (with the interconnections with the SCPMS data services)
  - The **Supply Chain Intelligence Wizard** (SCPMS 8 data service).

2 Overall introduction to the data services (inter-)relations – the basis of data services Benchmarking & Validation

The FBD_BModel Technology Platform is composed of two interconnected systems:

1. Cloud Computational Interactive Design System (CC_IDS), enabling designers to design personalized garments through interactions with consumers, and
2. Supply Chain Production Management System (SCPMS), enabling supply chain managers to optimize decisions at strategic, tactile and operational levels of the textile/fashion supply chain. Both CC_IDS and SCPMS and the corresponding business processes for product design and management are based on applications of 14 data-based services. Compared with the existing similar projects, development and application of these data-based services around the technology platform constitute the most important contribution of FDB_BModel, permitting to promote digitalization and "intelligentalization" in the fashion industries and create relevant B2B2C business models.

Concretely, CC_IDS is associated with 6 data-based services as follows.

- IDS1: Modelling and classification of body shapes of a specific population.
- IDS2: Identification of the individual consumer's needs (consumer profile).
- IDS3: Recommendation of relevant fashion design solutions to designers according to the personalized fashion requirements of consumers.
- IDS4: Recommendation of relevant functional design solutions (functional performances of materials) to designers according to personalized consumer's requirements on lifestyle.
- IDS5: Evaluation of virtual fitting in terms of fashion, fabric hand and thermal comfort of designed garments and adjustment of technical parameters according to evaluation results.
- IDS6: Creation, management and updating of the design cloud database and design knowledge base.
-

SCPMS is associated with 8 data-based services as follows.

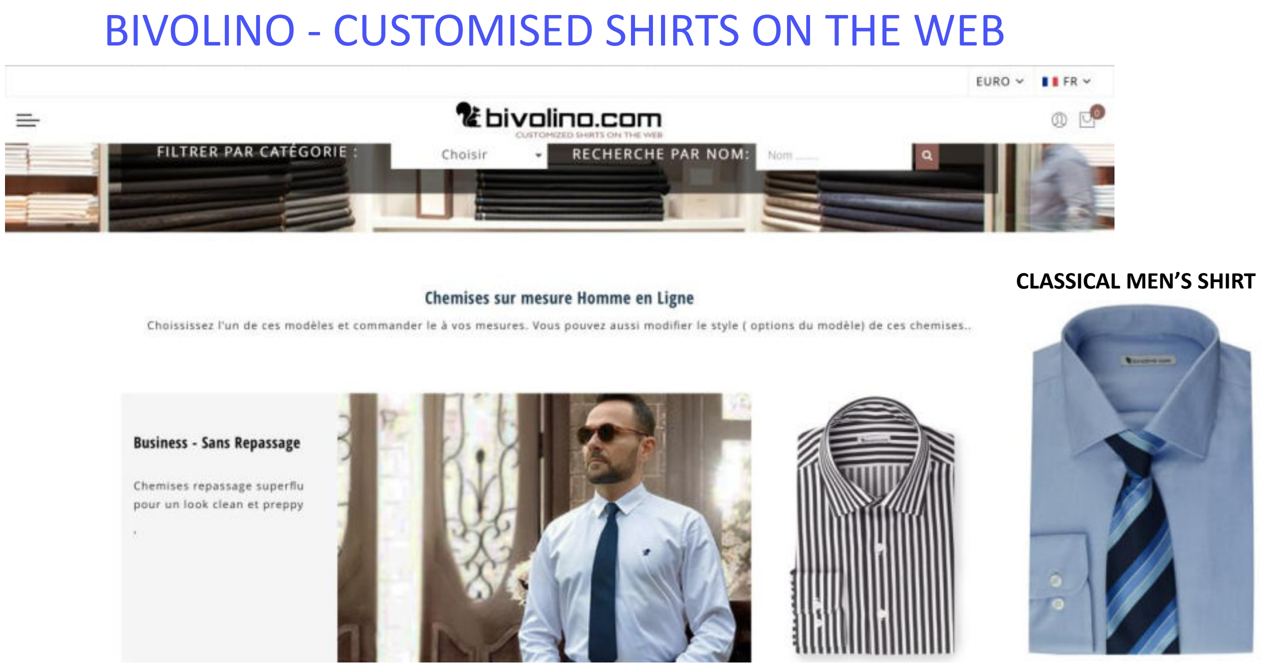
- SCPMS1: Selection of relevant fabric suppliers and materials as well as garment makers.
- SCPMS2: Testing and certifying functional performance of textile materials from fibres, yarns, and fabrics to garments for all the manufacturers in the fashion textile supply chain.
- SCPMS3: Cloud databases services for the certified textile and apparel manufacturers.
- SCPMS4: Optimization of production planning by dynamically organizing tasks into different series (reconfiguration).
- SCPMS5: Simulation of production and adjustment of tasks planning according to simulated performance.

- SCPMS6: Environmental footprint assessment (Life Cycle Analysis) and certification of products and manufacturing processes.
- SCPMS7: On-line pricing, trading and financial transaction services.
- SCPMS8: Creation, management and updating of the production knowledge base.

3 Presentation of the FBD_BModel Business Use-Cases & Training activities

Four business use-cases have been used for the scope of benchmarking & validating (through training & piloting activities), the FBD_BModel data services:

3.1 Business Case 1: Fashion Shirts Made-to-Measure (M-t-M) - BIVOLINO company



The idea of **Bivolino's use-case** it is to demonstrate in this frame a Big Data driven B2C and B2B2C co-creative business model for made-to-order (M-t-O) & made-to-measure (M-t-M) fashion in men's shirts. The garments will be processed through a virtual e-commerce driven supply chain with potentially zero returns, and a sustainable eco-footprint manufacturing in the Mediterranean area. Hence the mainly required technical features for Bivolino products are made-to-measure and easy-care (e.g., no-press, washability), breathability and thermal comfort on the skin are also two important parameters, as well as other added-value functionalities: stain resistant; anti-static; anti-microbial. The production process is characterized by a customization, on-demand, made on digitally printed fabrics with made-to-measure shirt-cut files and real-time processed patterns, to be easily sewed and assembled in a single-piece manufacturing.

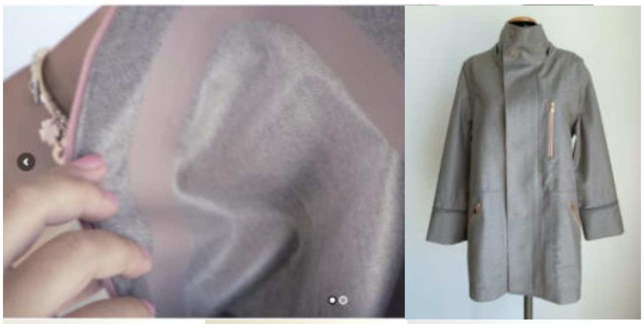
Figure 1. Bivolino product.

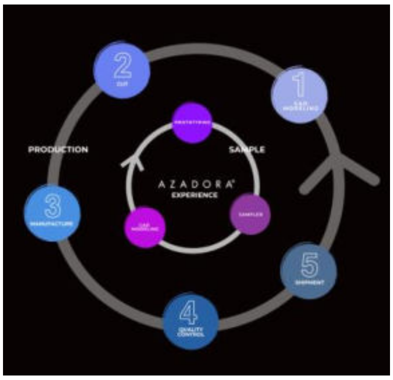
3.2 Business Case 2: Women's Fashion Outerwear - AZADORA company

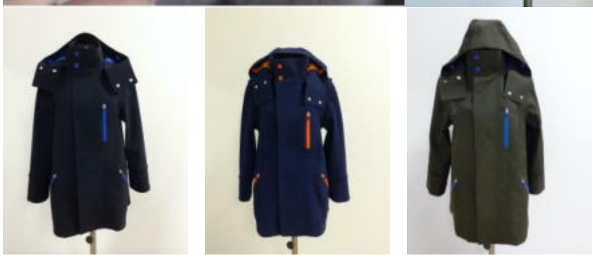
AZADORA - FASHION FAÇON FOR THIRD PARTY PRODUCTION

AZADORA

STYLISH WOMEN'S JACKET





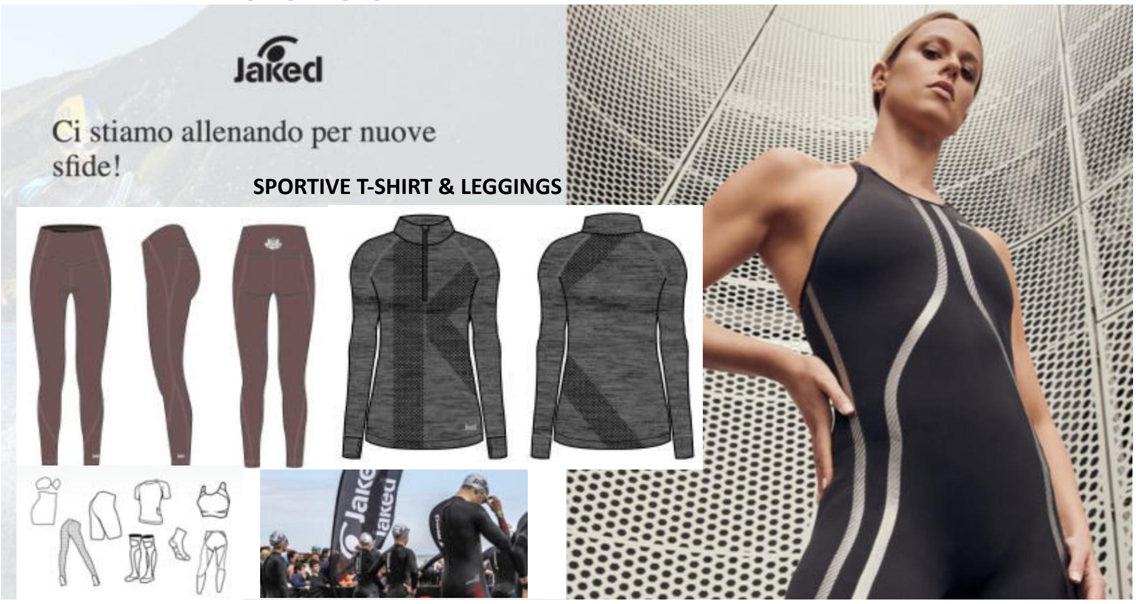


Azadora use-case will use in its Business Model the possibilities of Big Data in order to sell via Web shops & Digital shops (B2C) personalized garments for women's wear, also using co-branding for high-end and fashion luxury markets (B2B). The product line will be focused on the concept of a multi-garment set-up, in which, using a garment modularity approach, the final product can be potentially made of parts being attachable, detachable, foldable, through which a multi-configuration of the garment can be easily achieved. Personalization on materials and accessories' packages will be also provided.

Figure 2. Azadora product.

3.3 Business Case 3: Technical Performing Underwear - KUVERA company

JAKED/YAMAMAY (KUVERA) – FASHION & SPORTIVE BRANDS GROUP



The Business Model of **Kuvera use-case** is the focus on E-Commerce selling via Web using digital channels by targeting the following consumer groups:

- All sports addicted people but also for daily use.
- Disabled people that need a great customization.
- All people with especially physical characteristics.

As the supply chain at the moment, it is mainly located in Asia, it's so wanted to establish new suppliers in the EU and Mediterranean area.

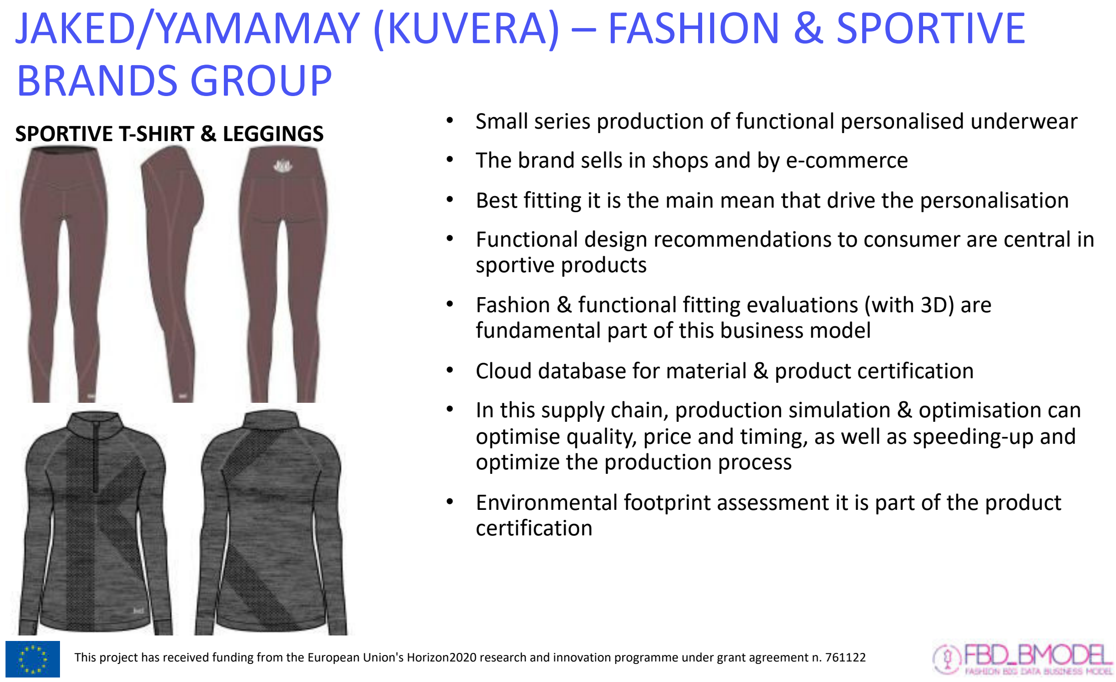


Figure 3. Kuvera products.

3.4 Business Case 4: Men’s Fashion Urban Wear. - BESTE company

In its Business Model **Beste use-case** wants to use the possibilities of Big Data and supply chain solutions to support its digital strategy of selling via the Web, of a unique product line coming from the deliberate encapsulation of a typical outerwear performing style to a sense of “aesthetic” akin to the most fashionable and urban collections, putting into play a series of technological skills and innovative digital tools. In the Beste Business Model, the garment It is not only a barrier or a necessary tool used to protect oneself from a hostile environment, indeed the garment it is a bridge, a second skin, a tool for the interactive e-dialogue, for the e-communication of the customer with the surrounding urban environment.

Figure 4. Beste product.

3.5 Training

Training sessions on the data services, happened the 18th-21st of January 2021:

- **18th of Jan 2021** - UOM & ENSAIT, FBD Functional CC_IDS Training Session 1: introduction to FBD Functional CC_IDS (IDS 2, 4, 5, 6 & 7 + SCMPS 2); how to use FBD Functional CC_IDS (IDS 6); how to identify consumer needs (IDS 2); how to recommend garment functional design to targeting consumers; introduction to FBD Fashion CC_IDS (IDS 1, 3, 5 & 6).

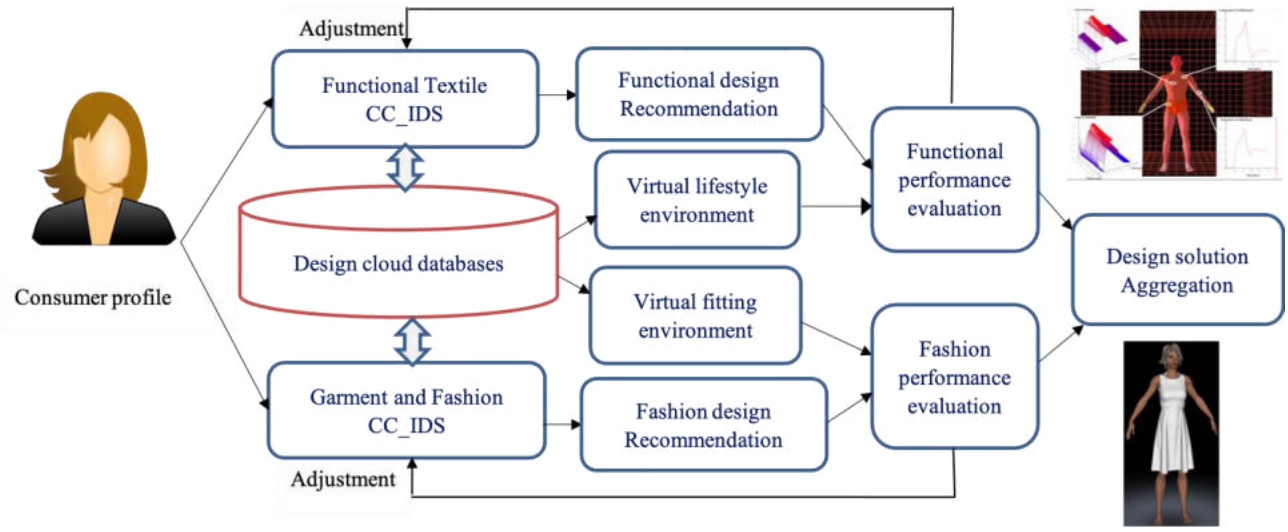


Figure 5. CC_IDS architecture.

- **19th of Jan 2021** - UOM, FBD Functional CC_IDS Training Session 2: how to test and digitize functional properties of fabrics; how to obtain sensory and thermal comfort performance of garments using the FBD Functional CC_IDS (IDS 5 & 7); how to maintain and manage FBD Functional CC_IDS (IDS 6).

- **20th of Jan 2021** - ENSAIT, FBD Fashion CC_IDS + SCPMS Training: introduction to FBD Fashion CC_IDS (IDS 1, 3 & 6); how to use the FBD Fashion CC_IDS recommendation system (IDS 3); how to adjust design solution and update design knowledge base (IDS 6); how to digitalize fabrics and garments (IDS 7); introduction to FBD SCPMS (SCPMS 1, 4 & 5); how to select relevant fabric supplier (SCPMS 1); how to process dynamic production orders (dynamic planning) and make simulations (SCPMS 4 & 5).

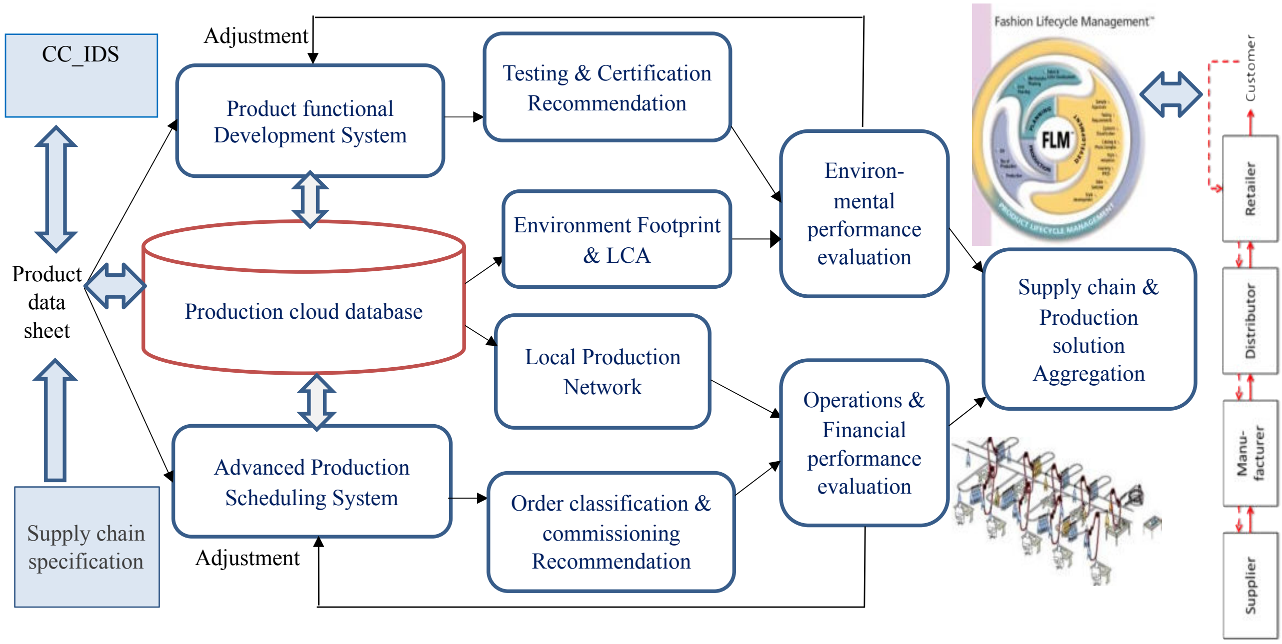


Figure 6. SCPMS architecture.

- **21st of Jan 2021** - HB, SCPMS Training: supply chain intelligence wizard training (SCPMS 8).

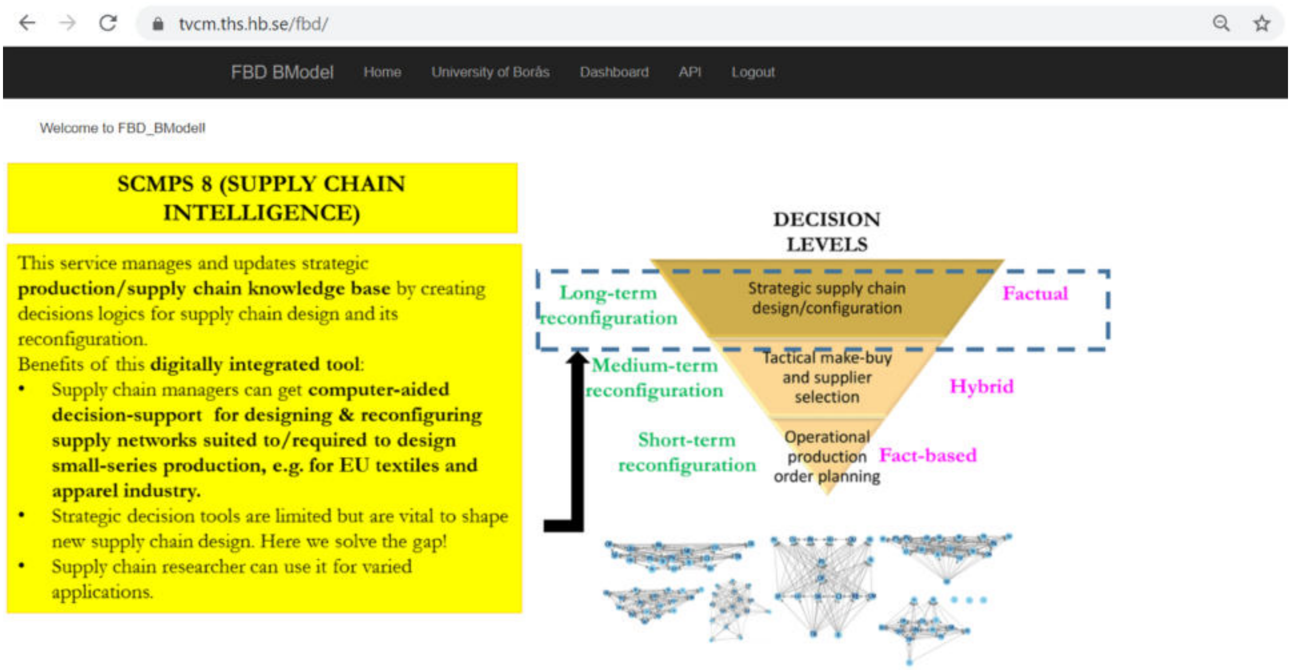


Figure 7. Supply Chain Intelligence Wizard (SCPMS 8).

4 FBD Functional CC_IDS + SCPMS (IDS 2, 4, 5, 6 & 7 + SCMPS 2) Benchmarking & Validation

The Functional Textiles CC_IDS is based on the multi-scaled computational clothing functional CAD system developed by UoM.

The Functional Textile CC_IDS is developed on the basis of modelling and simulating human thermophysiological responses and their interactions with clothing materials and external environments to link thermal comfort and functional performances of apparel products with fabric/fibre structural features and their functional properties. This system consists of a number of databases:

1. metabolisms of human activities;
2. human living environments in relation geographic locations and seasonal weather changes;
3. human anthropological features such as height, size, gender and age;
4. garment design and structural features such as size, fitness and layers in each garment, and the process of how to wear the garments (e.g., underwear + shirt + jacket + coat);
5. fabric structural and physical properties such as fabric thickness, weights, porosity, surface energy, water vapour permeability, moisture management properties, thermal conductivity, temperature regulating, IR irradiative property and smart heating capacity;

6. fibre structural features and properties such as diameters, surface energy, moisture sorption capacity, thermal conductivity.

IDS 2 is to collect quantify and Identify of the individual consumer's needs (consumer profile) in relation to their lifestyle in terms of physical activities, living environments, body size and shape and their physiological features and health status which is achieved by B2C gateway or APIs. IDS 4 (related to testing and certifying material and garment performance in SCMPS 2) presents functional performances of materials and garment to designers/consumers according to personalized consumer's requirements on lifestyle. IDS 5 (Functional design solution evaluation and adjustment) support the internal business activities of the fashion companies to cost-efficiently evaluate the product functional performance and make adjustment of garment functional design according to consumers' wearing scenarios. IDS 6 creates the design knowledge base to store all collected data from B2C gateway or testing and certification which includes all the database mentioned in functional CC_IDS. IDS 7 presents the digitalization process of textile materials from fibres, yarns, fabrics to garments for all the manufacturers in the fashion textile supply chain through testing and certifying of the functional performance. Data services generated during the IDS 7 are illustrated in Figure 11.

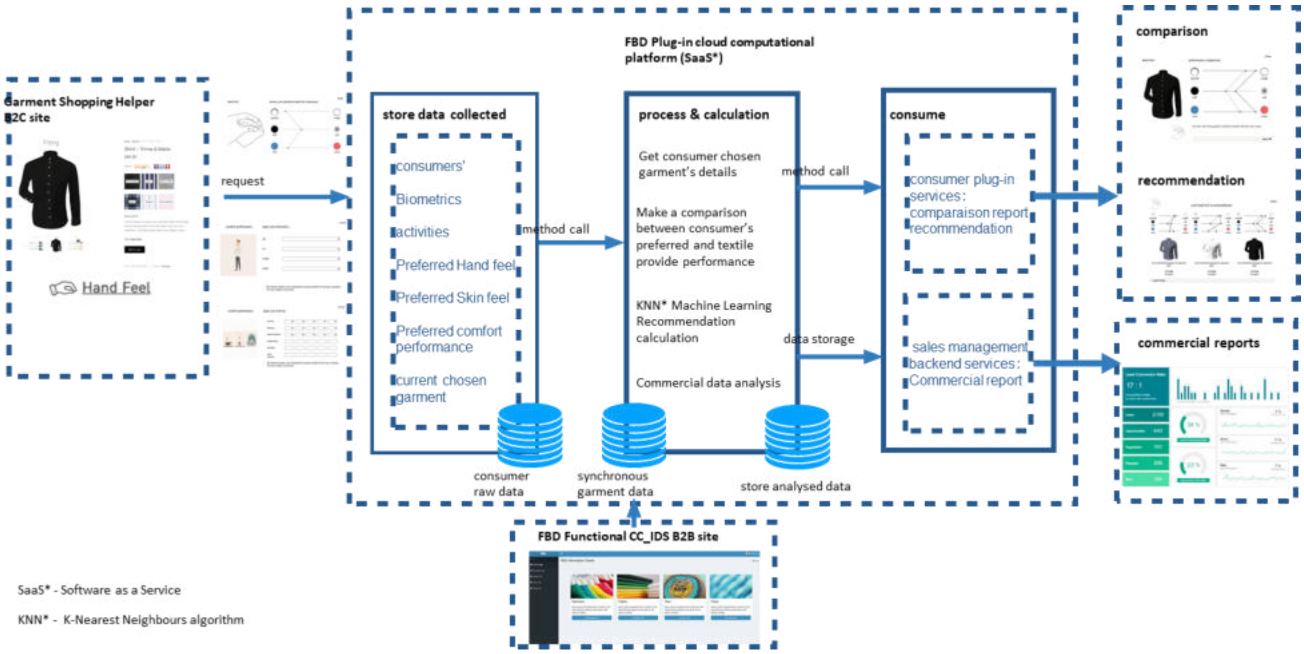


Figure 8. Functional CC_IDS information flow.

As it illustrated in Figure 8, functional CC_IDS database store all collected data whether from business partners or consumers. Currently, the B2B database web link is https://b2b.digital-clothing.co.uk/. The registered business partners could test and evaluate the fibre, yarn, fabric to garment database.

The consumer profile including lifestyle, living environment, sensory needs and functional needs are collected from B2C gateway through three APIs (Hand feel API, Skin feel API and Thermal comfort API) which could be accessed through this link: https://digital-clothing.co.uk/our-demo/.

The design logic of these three APIs follows the four stages: data collecting, data presenting, recommendation and feedbacks. The collected data from APIs forward to the database while simulated data from B2B database are presented in APIs after the requesting. The recommendation system is based the KNN method which could be further improved with the following feedbacks from transaction orders and consumers. The relationship between the database and APIs is illustrated in Figure 11.

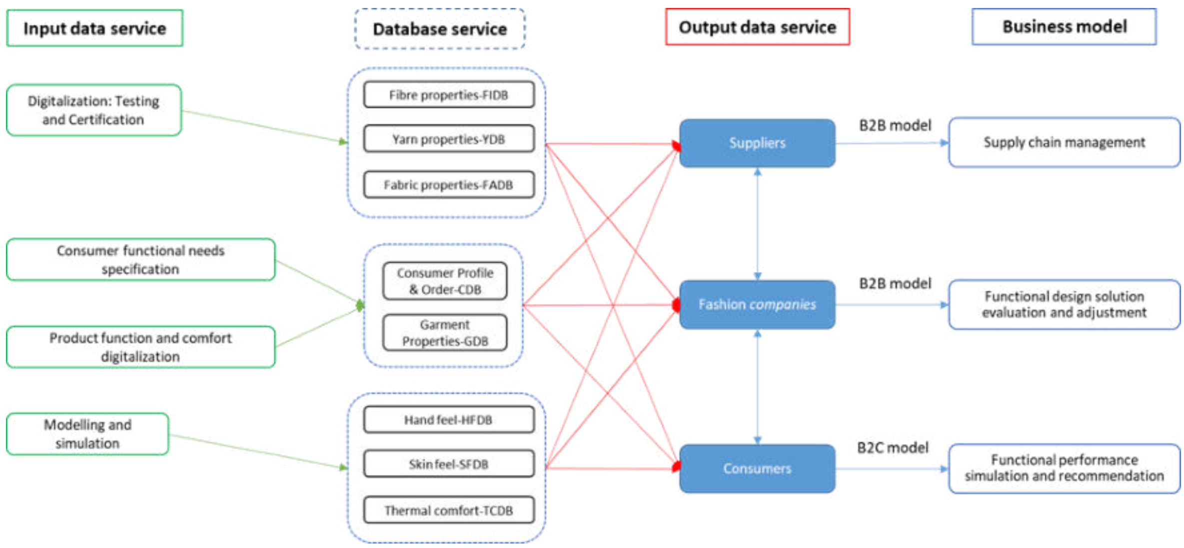


Figure 9. Functional CC_IDS data service and business model.

Figure 9 summary the data services of functional CC_IDS including input data service, database service and output database. Input data service refers to the digitalization of material properties, consumer lifestyle needs and preferences as well as garment functional performance and sensory comfort. These data are acquired respectively through testing and certification, consumer psycho-physiological needs specification, product functional and sensory comfort digitalization, as well as modelling and simulation.

Database service refers to data storage and the management of the digitalized data from input data service. Output data service refers to the analysis of the data in the form of commercial reports to assist businesses in product innovations, strategic or operative decisions, including product design analysis, material usage analysis, product analysis, market sale analysis as well as supplier analysis. According to the different end-users or purpose of the data service, B2B or B2C business model could be built. For suppliers, the output data service can be used to build a knowledge-based supply chain management system that is transparent and systematic.

For fashion retail companies, functional performance and sensory comfort simulation results can provide a rapid and cost-efficient method to evaluate the functional performance of a garment and in helping them make key design decisions.

For end-of-users, a friendly user interface smart recommendation API plugin can enable consumers to shop online with more comprehensive information on a garment 's hand feel, skin feel and wear comfort performance as they are shopping in shops and they can compare the sensory performances with their real wear experiences and give feedbacks on their level of satisfactions. Figure 10 illustrates the business structure based on FBD_BModel digital platform (CC_IDS and SCPMS).

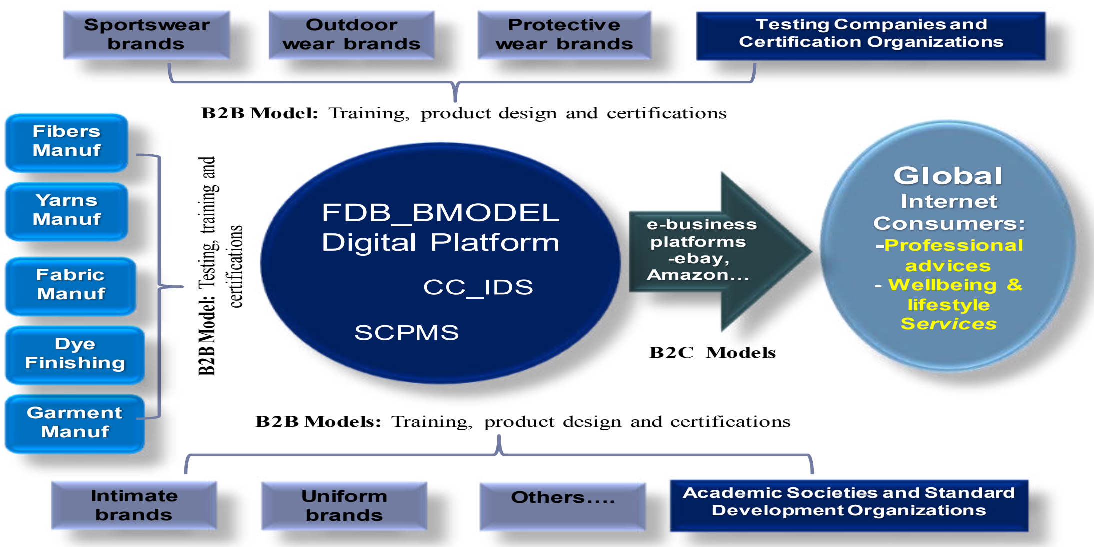


Figure 10. Functional CC_IDS business framework.

Material physical testing report and garment simulation results report in Figure 11 are deliverable results to business partners. They are main input contents in B2B database which serves the suppliers, manufacturers and fashion companies in the supply chain. The B2C database stores the temporary data from API and performing as the communication socket between API and B2B database. The design of B2C database is to satisfy individual consumers' sensory and functional needs.

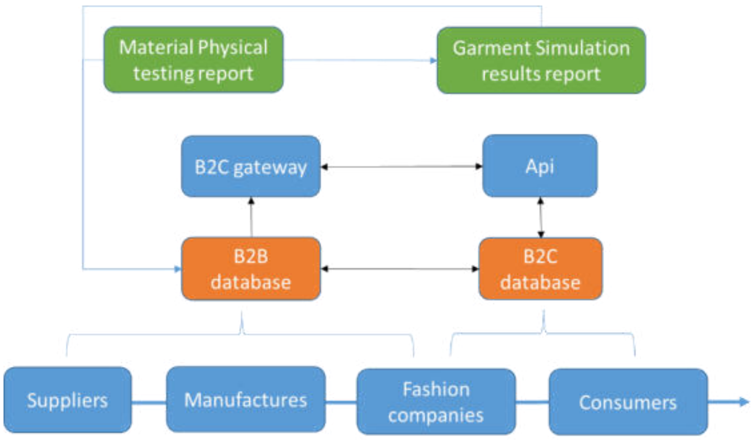


Figure 11. Output of functional CC_IDS and database service.

Under the development of Industry 4.0, frequently discussed technologies and concepts within the validated literature are summarized in Figure 12. Taking the functional CC_IDS into consideration with this framework, the achieved characteristics are coloured with green box and the potential easy-achieved features are coloured with yellow box.

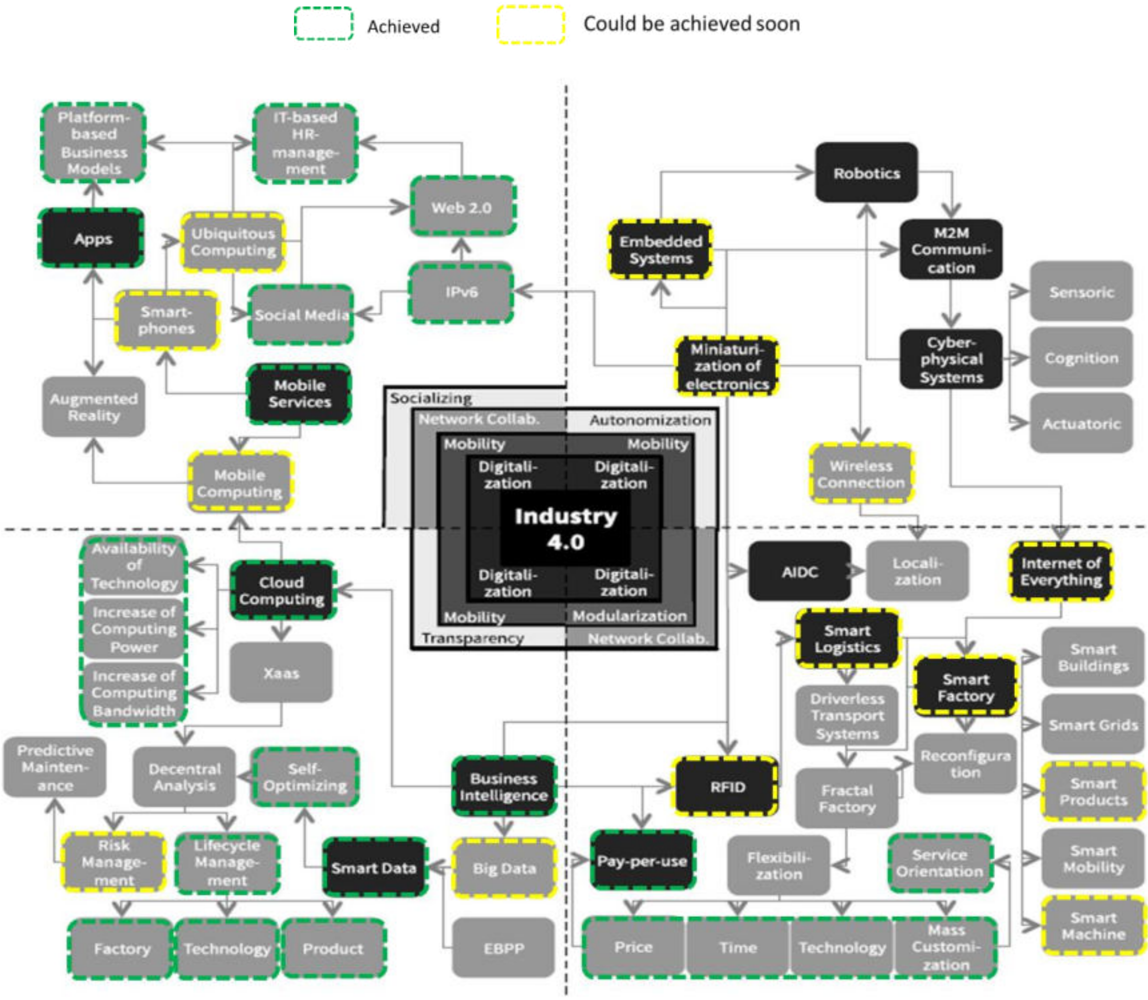


Figure 12. Mind-map of technologies and concepts in Industry 4.0 [1].

The availability of data services of Functional CC_IDS is benchmarked against the current commercial fashion e-shopping platforms and/or websites of e-retailing companies. As shown in in Table 1, a number of B2C websites that are commercially operating and selling fashion textile products to consumers and offering sizing fitting recommendations. These e-shopping platforms such as Bivolino, Fittizy, Amazon, JingDong (China), eBay, Taobao, Asos, Zalora and Uniqlo provide a range of e-shopping services: such as outlook (product photos), price, delivery time, SKU (details of products). Some of the B2C websites also provide garment size fitting recommendation and modalized style selection/design. Fashion CC_IDS could also provide the size fitting service with 3D virtual review. However, **the data services provided by Functional CC_IDS are not available from those B2C websites, which are completely new**. It could be concluded that the functional design, sensory and functional performance as well as the material and garment digitalization process are only available in functional CC_IDS. The data services provided from Functional CC_IDS include:

1. UoM-IDS-R1: IDS Services and Databases Bundle - Functional CC_IDS.
2. UoM-IDS-R2: Fabric and garment functional design B2B database (IDS6).
3. UoM-IDS-R3: Identification of the individual consumer's needs and consumer profile (IDS2).
4. UoM-IDS-R4: Garment functional and sensory comfort design recommendation system (IDS4).
5. UoM-IDS-R5: Garment functional and sensory comfort design matching model (IDS5).
6. UoM-IDS-R6: Fabric functional properties digitalization process (IDS7).
7. UoM-IDS-R7: Garment sensory comfort performance digitalization process (IDS7).
8. UoM-IDS-R8: **Fabric hand feel fit, garment skin tactile sensory fit and clothing wear physiological fit** APIs design (IDS7).

These data services from Functional CC_IDS are new and unique to consumers and companies in fashion and textile supply chain. Through these data services, big data technology platform will be established to link the whole fashion textile supply chains directly and digitally to generate cost-effective and more sustainable business models.

Table 1. Benchmarking of data service in functional CC_IDS.

Data service	No	Functional CC_IDS	Fashion CC_IDS	Bivolino	Fittizy	Amazon	JingDong	eBay	Taobao	Asos	Zalora	Uniqlo
UoM-IDS-R1: IDS Services and Databases Bundle - Functional CC_IDS	1	v										
UoM-IDS-R2: Fabric and garment functional design B2B database (IDS6)	2	v										
UoM-IDS-R3: Identification of the individual consumer's needs and consumer profile (IDS2)	3	v										
UoM-IDS-R4: Garment functional and sensory comfort design recommendation system (IDS4)	4	v										
UoM-IDS-R5: Garment functional and sensory comfort design matching model (IDS5)	5	v										
UoM-IDS-R6: Fabric functional properties digitalization process (IDS7)	6	v										
UoM-IDS-R7: Garment sensory comfort performance digitalization process (IDS7)	7	v										
UoM-IDS-R8: Garment sensory fit APIs design (IDS7)	8	v										
Garment size fit recommendations	9		v	v	v					v	v	v
E-shopping services: photo, price, delivery time, SKU (details of products)	10	v		v	v	v	v		v	v	v	v

The integration of Fashion CC_IDS and Functional CC_IDS can provide comprehensive data services from fashion textile consumers to the companies in the whole fashion textile supply chain.

5 FBD Fashion CC_IDS + SCPMS (IDS 1, 3, 5, 6 & 7 + SCMPS 1, 4 & 5) Benchmarking & Validation

The data-based services (IDS1, IDS3, IDS5 and IDS6) constitute the basic functions of the Fashion CC_IDS, aiming at designing garments meeting the consumer's personalized body measurements and fashion style requirements. IDS1 is an internal offline procedure enabling to create parametric 3D human models for a given population in Europe and allocate a specific consumer to the most relevant 3D human model of the existing human database according to his/her personalized measurements. The other three data-based services (IDS3: design recommendation, IDS5: 3D garment demonstration and evaluation, IDS6: design adjustment and knowledge base) form a new working process, namely design recommendation – 3D virtual garment fitting demonstration and evaluation – design adjustment, which can be run iteratively. IDS7 is a user's guideline enabling to teach step by step designers or design amateurs to digitalize fabrics and garments. It is linked to the digital library for visualizing all digitalized garments of the 4 business cases (Bivolino, Azadora, Kuvera and Beste). The proposed working process for realizing a personalized garment design using the services of IDS3, IDS5 and IDS6, is illustrated in Figure 13.

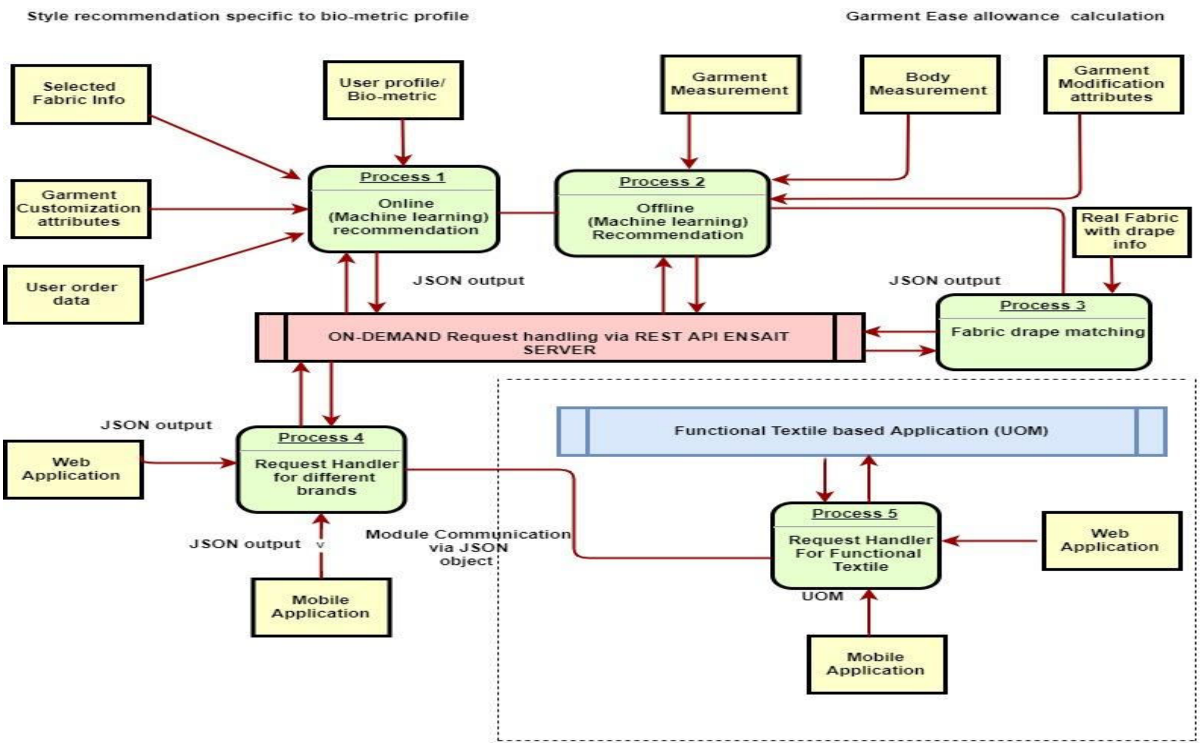


Figure 13. Working process for a personalized design case (FBD Fashion CC_IDS).

In this working process, all operations of the Fashion CC_IDS from Process 1 to Process 4 are related to the on-demand request handing via the REST API ENSAIT SERVER. Process 1 enables to realize style recommendations related to the consumer biometric profile. Process 2 deals with garment ease allowance computation from the human body and garment measurements. Process 3 permits to select the closest virtual fabric and its technical parameters from the database associated with the 3D garment CAD software by performing drape shape matching between virtual fabrics of the database and the preselected real fabric. Process 4 is a request handler for different brands. Together with Process 5, Process 4 also enables to set up communications and interactions between Fashion CC_IDS and Functional CC_IDS, namely between design elements and textile technical parameters at different levels (yarns, fabrics, garments).

The entry address of the working process is http://gfrs.ensait.fr/. The user can test and try the API methods using the above link before integration. The Authentication Token for testing Request token is: qxerponyfgma1&2#az (see Figure 14). All the digital garments used in this process can be visualized at http://gfrs-visual.ensait.fr/. Next, we take Bivolino men's shirt as a design case to illustrate and validate the Fashion CC_IDS working process.

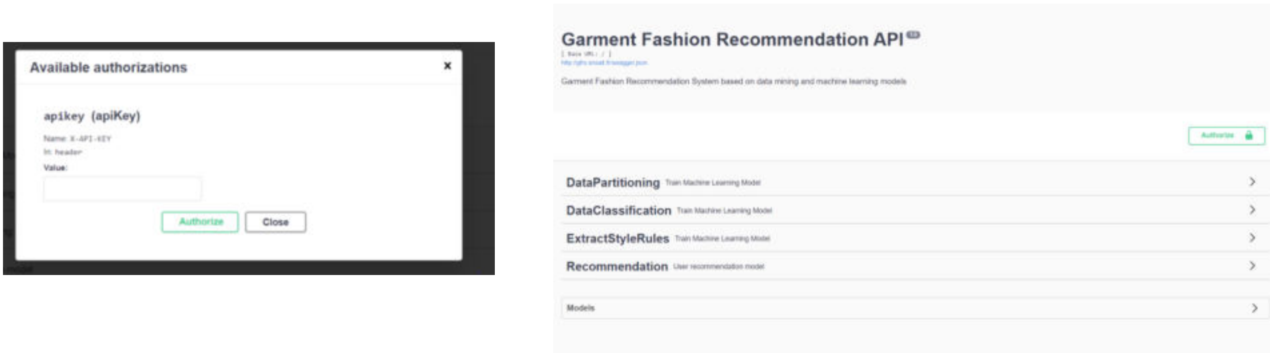


Figure 14. The working process home page and authentication taken.

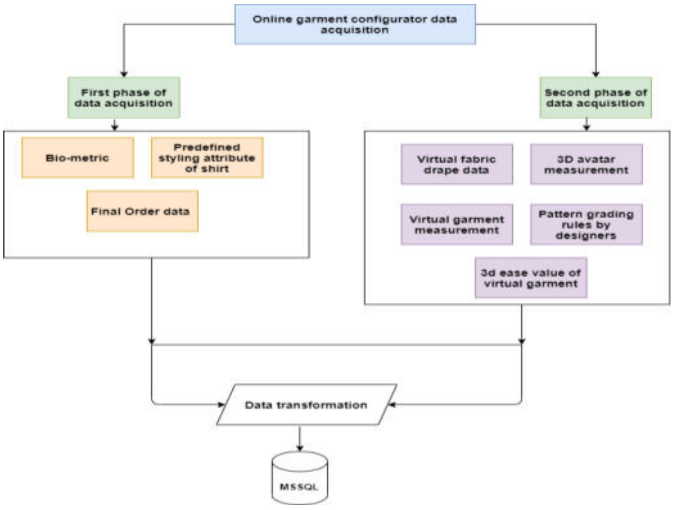


Figure 15. Architecture of the garment design knowledge base (IDS6).

The garment design knowledge base is the key component of the Fashion CC_IDS process. Its online garment configurator data acquisition module enables to acquire real data on consumer biometric profiles, garment styles and orders, and virtual data (virtual fabric drape, 3D avatars, 3D virtual garments, garment pattern grading rules, 3D virtual ease values), and store them in a database after data transformation (see Figure 15). This design knowledge base has been enhanced by introducing a set of representative virtual fabrics and their technical parameters (weight, fibre composition, thickness, mechanical properties in warp and weft for bending, tensile and shearing), a set of 8 representative avatars (3D human models) and their key body measurements, a set of 8 standard garment sizes and corresponding dimensions (length, breast girth, sleeve length, sleeve opening), 5 pattern rules and corresponding 3D ease allowance values of garments related to the 8 previous human models, regular fit and 5 representative fabrics.

For recommending a personalized garment, the user first inputs the biometric profile corresponding to his personalized men's shirt, including height, collar size, weight and age, and selects the desired garment fit style from {Regular Fit, Slim Fit, Super Slim Fit}. The predefined styling attributes, including collar style, cuff style, fabric and final order, are also selected at this stage (see Figure 16).

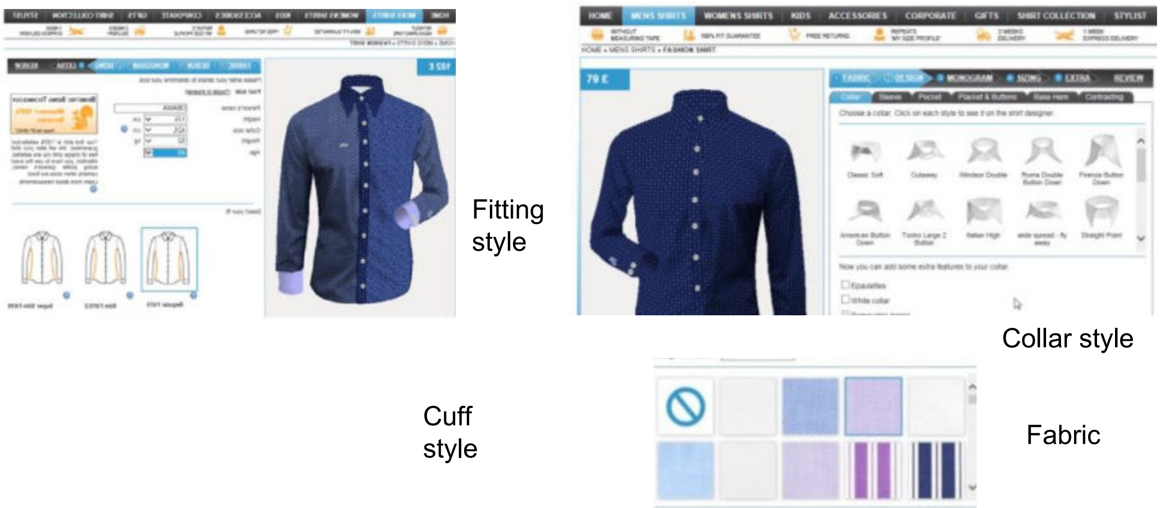


Figure 16. Biometric profile input and selection of garment styling attributes.

Based on the design knowledge base, the recommendation system generates several ranked design solutions according to the input data (biometric profile and style section). These initially recommended design solutions represent the garments having the highest relevancy degrees related to the input data, automatically selected from all combinations of the standard garment sizes and fabric samples existing in the knowledge base (see Figure 17). Each recommended design solution is composed of 1) standard garment size (with identified key dimensions), 2) style attributes for fabric, collar and cuff, 3) garment colour and 4) fitting style. The corresponding 3D garment fitting can be generated from these parameters. However, the recommended garment with the highest relevancy degree is not necessarily satisfied by the involved consumer and designer. A design adjustment process will be carried out based on the currently recommended solution according to the rules defined in the design knowledge base (see Figure 18).

Figure 17. Initially recommended design solution.

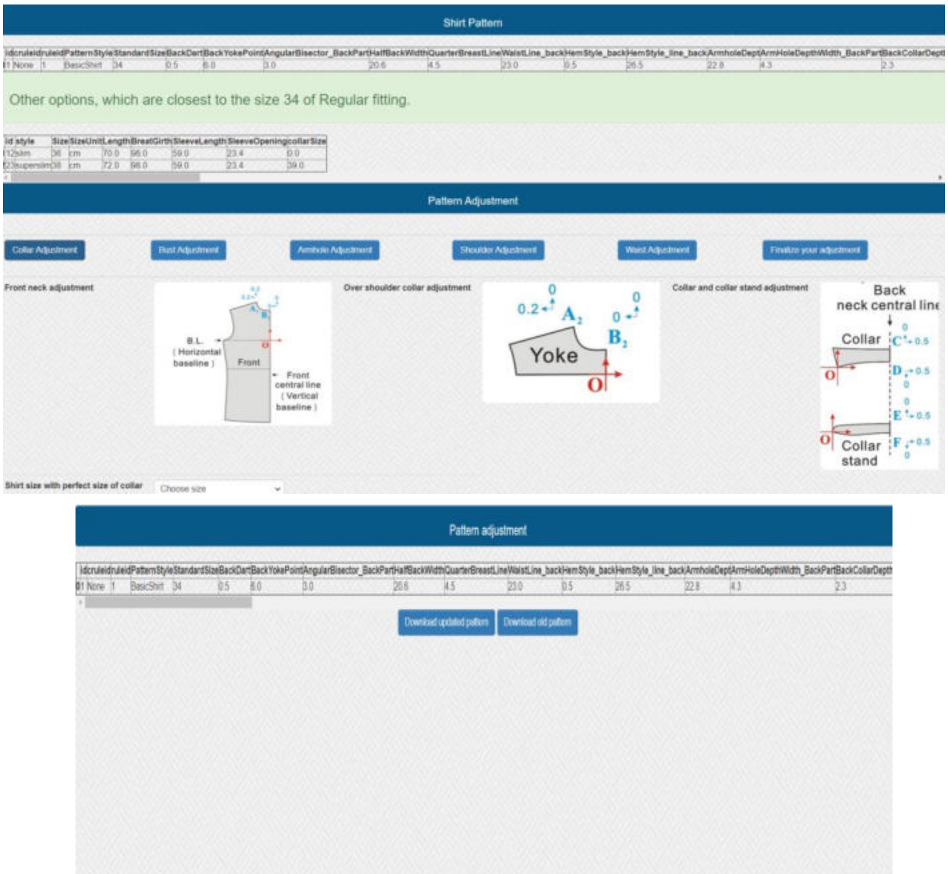
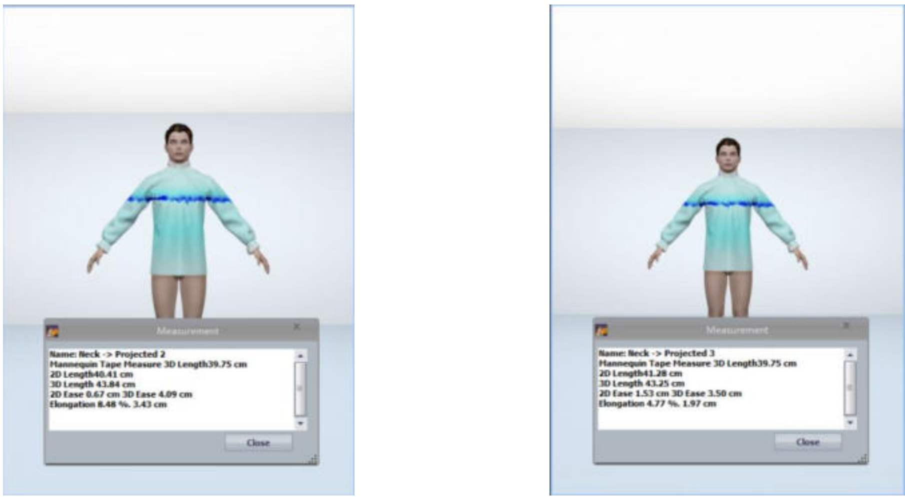


Figure 18. Pattern adjustment.

(a) Fashion image before the adjustment

(b) Fashion image after the adjustment



(c) Garment pressure image before the adjustment

(d) Garment pressure image after the adjustment

Figure 19. Comparison of virtual garments before and after the design adjustment.

The design solutions before and after the adjustment can be transformed into the 3D garment fitting effects and demonstrated in a virtual environment (see Figure 19). For this example, the difference of visual effects for these two design solutions is slight. However, we can find from the numerical parameters of the garment pressure images (c) and (d) that there is a difference at neck position. The neck length of the human model is 39.75 cm. The garment neck length is 43.84 cm before the adjustment and 43.25 cm after the adjustment (0,6 cm shorter). From its elongation value, the fabric has become a little tight. All these changes mean that the adjusted garment gives more fitting effects and closer to the wearer's body surface. In the cases of tight style clothing such as legging, this change can be more evident.

The data-based services (SCMPS1, SCPMS4, SCPMS5) constitute an important component of the Supply Chain and Production Management System (SCPMS). The entry of these data-based services is http://scpms.ensait.fr/. The general principle of these three data-based services is described in Figure 20.

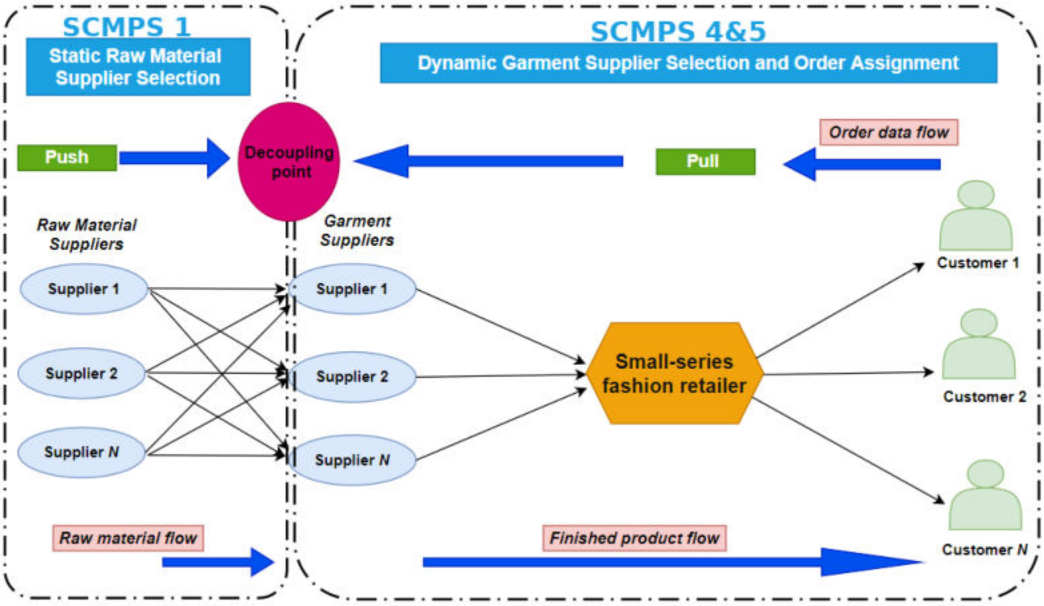


Figure 20. General principle of SCPMS1, SCPM4 and SCPM5.

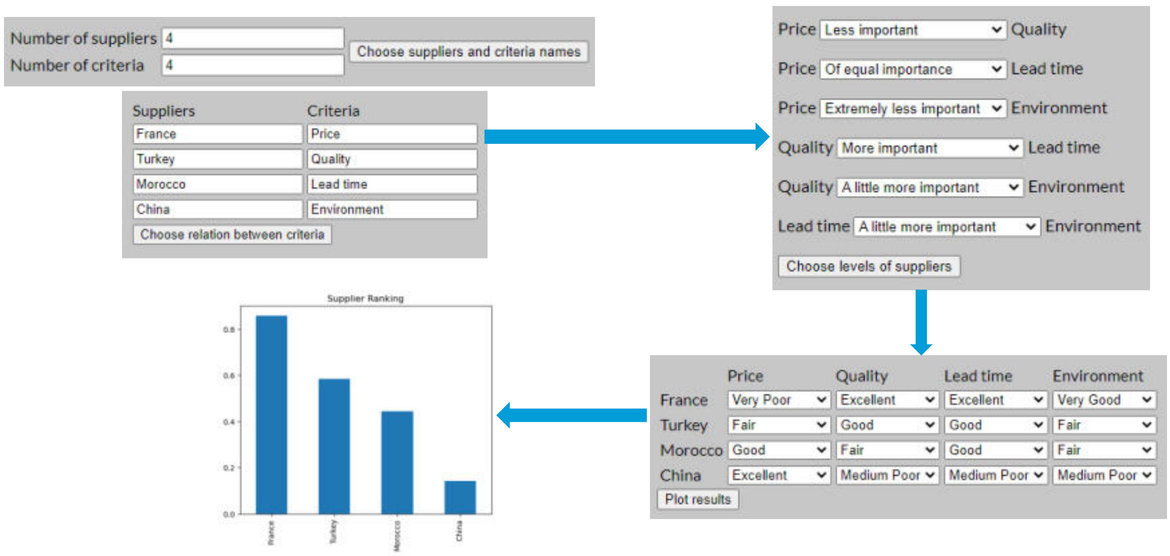


Figure 21. One example for ranking 4 suppliers with 4 criteria.

For running SCPM1 (supplier selection), the user (supply chain manager) needs to first input their criteria of selection and pairwise comparison results between these selected criteria. The comparison results or relative importance levels take values from {*Extremely less important, less important, a little less important, equal importance, a little more important, more* *important, extremely more important*}. The used criteria usually include “price”, “quality”, “lead time” and “environment impact” but can also integrate new ones according to specific requirements of the supply chain management. Next, the user needs to give his/her qualitative evaluations of the involved suppliers related to these criteria in order to obtain the final ranking result. One illustrative example is given in Figure 21. According to this result, we can find that the supplier in France is the best one in terms of price, quality, lead time and environment impact.

SCPM4 and SCPM5 are run together in order to dynamically allocate production order to garment makers with graphical simulation results, showing the performance indices of this process. The process of order planning and simulation starts with inputting data on suppliers (garment makers) and production orders. One example of order planning and simulation results at time=15 is given in Figure 22. In this example, there are 5 suppliers and 20 orders. Each supplier is characterized by its production unit cost, delivery cost, first available date, production unit time and delivery time. Each production order is characterized by its required quantity, price and expected delivery time. In Figure 22, the dynamical status of order execution for each supplier, including order status, overall processing time, profit, rate of delayed orders and mean delayed time, can be visualized from the numerical and graphical simulation results. At time=15, we can find that the orders {111, 118, 119, 127, 116} are allocated to the supplier 11, in which the orders 111 and 118 have been processed without any delay (green colour, effective delivery time of 111 is 7, earlier than its expected delivery time (12)), the order 119 is being processed (blue colour, expected delivery time=18), and the two orders (127, 116) are put in the waiting file.

Suppliers data, current time = 15							
id	Next orders	Current orders	Orders done	Time	Profit	%Late	Mean late
11	116; 127	119	118; 111	46	40.0	0.0%	0.0
12	128	122	129; 123	28	60.0	0.0%	0.0
13	None	114	130; 113	18	45.0	0.0%	0.0
14	121; 120; 125	117	115	50	40.0	0.0%	0.0
15	124	126	112	26	45.0	0.0%	0.0
Mean					230.0	0.0%	0.0

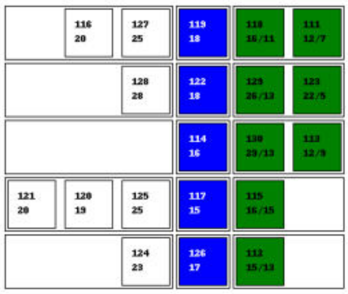


Figure 22. One example for showing results of order planning (SCPMS4) and its simulation (SCPMS5).

6 FBD SCPMS 8 (Supply Chain Intelligence Wizard) Benchmarking & Validation

The data service SCPMS 8 "Supply Chain Intelligence Wizard" (available at the Web link: https://tvcm.ths.hb.se/fbd/) it is developed by Textile Value Chain Management Research Group of University of Borås in the scope of the FBD_BModel project. This service manages and updates strategic production/supply chain knowledge base by creating decisions logics for supply chain design and its reconfiguration. The goal of this digitally integrated tool is to help supply chain managers in receiving computer-aided decision-support for designing & reconfiguring supply networks suited to/required to design small-series production, e.g., for EU textiles and apparel industry. Such strategic decision tools are limited in availability but are vital to shape new supply chain design for tomorrow's production and supply chain management. Supply chain researcher can use it for varied applications.

The validation of the results of the dynamic strategic decision support tool (SCMPS 8) developed within the scope of FBD_BModel project, was devised by first conducting a questionnaire-based digital interview with the four (4) business use-cases in order to understand the key interdependencies between SNCC (Network Design/Configuration and Capability) aspects when configuring for small-series production in EU context. Subsequently, the tool was utilized to generate various SC Intelligence models, and these were verified by seeking explanations, and thus extending them, through qualitative discussions with the respondents.

6.1 Validation methodology

The overall validation process followed for this data service is as follows:

STEP 1. Check the internal validity of the SNCC model aspects (Table 2) with the business cases partners.

STEP 2. Conduct structured interview to: (a) understand the status quo and plan for small- series production in EU for each business case, (b) explore the SNCC interrelationships and strengths on a scale of 0 to 4, and (c) seek supporting explanations.

STEP 3. Evaluate each case's SC Intelligence models I and II (based on established methods like TISM and MICMAC analysis, using graph theoretical approach), by setting manual threshold = 3.

STEP 4. Present preliminary results (including points to clarify) and seek explanations through follow-up interviews in order to highlight the interrelationships found in SC Intelligence models I and II.

STEP 5. Verify explanations and extend the discussions to identify/verify current state, opportunities and challenges for reconfigurations.

STEP 6. Generate final company results and validation report, as presented here.

6.2 Explanation of the models

This data-service is developed on the basis of a set of 17 relevant supply network design/configuration and capability (SNCC) aspects, derived through an extensive review of scholarly literature, followed by exploring their orientation in small-series and high-cost production contexts. Table 2 below summarizes these 17 aspects and explains these briefly.

These aspects are related to:

Product value structure: Related to product structure and composition. Such as levels of product variety, degree of modularity, product replenishment mode, e.g., made-to-stock, make-to-order.

Operations: Related to core activities and processes, infrastructure and tools. Such as ICT, flexible processes, cellular structures.

Network structures: Related to strategic structural decisions along the broader issues of supply chain design. Such as locations, tier structures, ownership and integration, complexity and flexibility.

Network relationships: Related to governance, complexity, trust, and the roles of network partners. Such as trust underpinning joint activities, knowledge-sharing and collaboration.

Supply chain capabilities: Related to mass customization capability, potentially gained from tighter suppliers' relationships. Such as responsiveness, sustainability and innovation, speed.

Table 2. SCPMS 8 construct.

	17 SNCC ASPECTS	CONTEXTUAL CHARACTERISTICS
Value Structure	**Product structure (architecture) (PS)**	X. Product complexity, high levels demanding supply chain co-location (R&D/production/market etc.) Y. Modularity/commonality of components for product variety management and mass customization
	Product variety (PV)	X. Volume and mix flexibility gained from proximity manufacturing Y. High volume/variety for responsiveness or mass customization requiring enhanced involvement
Unit Operations	**Specialized knowledge and production technologies (SK)**	X. Knowledge-based/advanced manufacturing and learning in high-cost contexts Y. Supplier, customer and internal technology, knowledge and learning enabling customization
	Operational flexibility and agility (OF)	X. Production/delivery flexibility motivating location decisions, and production system design Y. Process, capacity and workforce flexibility for customization

Network Structures	**Production/sourcing location (LO)**	X. Co-location, or production location decisions in relation to other supply chain stages for proximity. Y. Co-location for long throughput times and changeable components
	Structural flexibility (SF)	Y. Supply chain adaptability, complexity, and modularity
	Supplier integration (SI)	
	Internal integration (II)	Y. Infrastructures, practices and systems to be coordinated, e.g., information systems
	Customer integration (CI)	
Network Relationships	**Close/long-term relationships (RE)**	X. Collaboration with nearby suppliers and/or customers Y. Stability and collaboration with customers and/or suppliers for customer-specific production
	Communication and information sharing (CM)	X. Complexity of communication demanding co-location among supply chain stages Y. Visibility/openness, supported by digital technologies
	Trust and mutual commitment (TR)	Y. Relational governance and knowledge-sharing
Capabilities	**Customization (CU)**	X. Advantage/motivation for sourcing/producing locally Y. Customer involvement, product modularity and solution space freedom, i.e., personalization
	Innovation (IN)	X. Operational performance, related to product characteristics/changes and responsiveness Y. Innovation through customisation (knowledge specialization and variety) and organizational learning
	Sustainability (SU)	X. Performance increasingly in focus (environmental, social and economic), linked with quality and control Y. Performance increasingly in focus (environmental, social and economic)
	Quality (QU)	X. Increased performance and focus on customers and continuous improvement Y. Operational performance associated with mass customization capability
	Delivery speed/reliability (DE)	X. Operational performance motivating proximity, both virtual and physical Y. Operational performance associated with mass customisation capability

X. High-cost context

Y. Small series production context

The models generated through this automatic data service are called **SC Intelligence I and II**. The key features to interpret through these models are presented below.

6.2.1 SC Intelligence I

Here categorization of the SNCC aspects is made into a 2x2 matrix as Independent, Linkage, Dependent or Autonomous.

Independent: These aspects are mainly driving the development of other SNCC aspects crucial for designing your supply chain. Concentrate of these.

Linkage: These aspects are both driving and dependent on the development of other SNCC aspects crucial for designing your supply chain. These are intermediate and complexly interrelated aspects that you need to consider carefully.

Dependent: These aspects highly dependent on other SNCC aspects. If you develop the others, these will follow.

Autonomous: These aspects are neither dependent nor driving the development of other SNCC aspects crucial for designing your supply chain.

6.2.2 SC Intelligence II

In this visual graph the data service provides a tier-wise categorization of the SNCC aspects, based upon the supply chain decision-maker's responses. The model can be interpreted as follows:

Bottom level: represents that the aspects here are foundational for designing your supply chain.

Top level: represents that the aspects here are mainly driven by other SNCC aspects that are crucial for designing your supply chain.

Direct interdependence (in *GREEN*): This highlights the direct influence of one aspect on the other (denoted by arrow).

Transitive interdependence (in *RED*): This highlights the indirect, hidden influence of one aspect on the other (denoted by arrow) via an intermediate relationship.

6.3 Application of the models to the business use-cases

6.3.1 Bivolino

Business model: branded manufacturer/service (Bivolino – MTM shirts). Size: micro. Product focus: fashion shirts. Small series focus: 100%. Sourcing model: hybrid ownership. Stage of small series production implementation: already established.

Bivolino has a state-of-art digitally integrated production system for classic and fashionable made-to-order (MTO) and/or made-to-measure (MTM) woven garments, with the system designed to facilitate both B2B services and B2C sales.

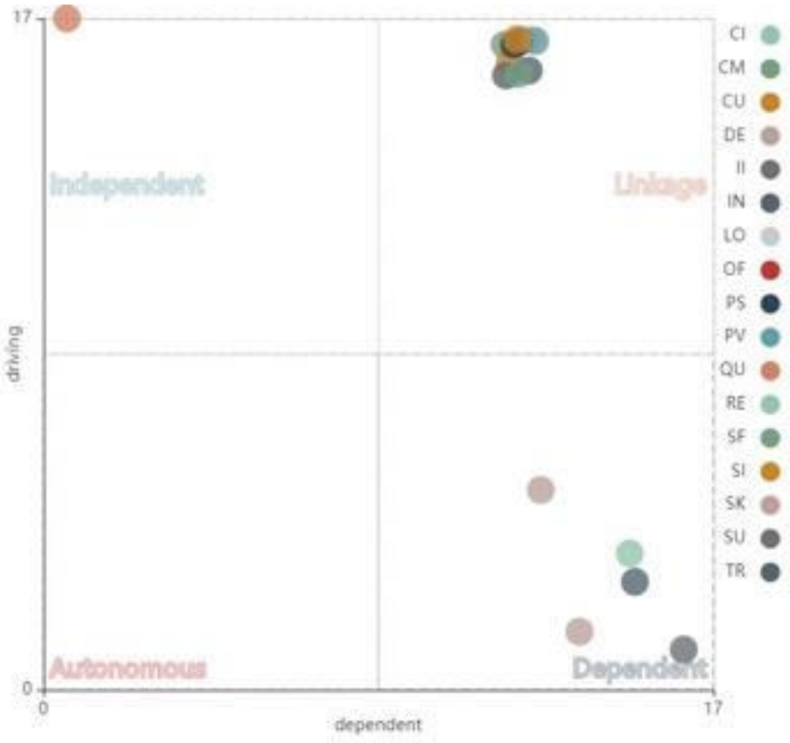
Its front-end processes are focused on seamless service with minimal effort of the customers. Various efforts have been undertaken to strengthen customer relationships and access customers more effectively include, e.g., establishing vendor-based sales and offering new product performance and sustainable materials.

Its regional hybrid ownership is characterized by investments into CAD/CAM technologies, such as digital cutters, whereby partners invest in workers and facilities. Such digitized processes are trusted more than interactions between people, and the only challenge is related to the worker-technology interface.

Bivolino's flexible production system highlights the importance of high skilled workers, along with automated data transfer. Thus, the process of development specifically demands commitment and organization of production companies to ensure extra capacity and ability to scale up and down quickly. Existing processes involve automatic reordering of fabrics, which requires development to improve and create seamless processes. Beyond internal development of systems, this demands efforts of fabric manufacturers to improve ordering systems. Additionally, co-branding with fabric brands are some efforts undertaken to strengthen relationships and appeal to customers.

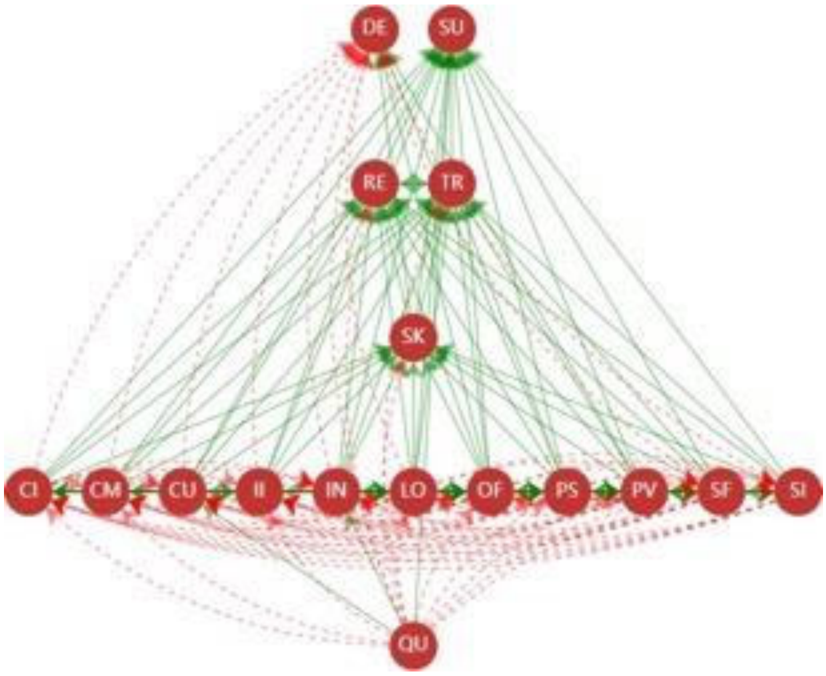
However, Bivolino's distributed manufacturing set-up spread across different established specialized production locations, along with fabric sourcing from different locations, are impacted by import taxes and bilateral agreements. Currency and trade turbulence is leading to the need for new competence in-house focused on supply chain management.

Table 3. Supply chain Intelligence I (Bivolino).



Autonomous	
Independent	QU
Dependent	DE RE SK SU TR
Linkage	CI CM CU II IN LO OF PS PV SF SI

Table 4. Supply chain Intelligence II (Bivolino).



6.3.1.1 Validation

The many interrelationships shown in the linkage aspects in SC Intelligence I, and level 4 of SC Intelligence II indicate the complexities of managing small series production due to presence of diverse interdependencies, specifically for MTM supply chain configuration. However, it is obvious that configuration is largely driven by high level of quality (including fit customization performance).

Some main strategies to handle in MTM supply chains include, enhancing existing customer relationships with vendor system, and increasing value of products through co-branding with fabric suppliers (likely to improve sustainability), and to bring supply chain knowledge in-house to manage volatility. Based on having established production regionally, Bivolino significantly focuses on changing its production system design to strengthen existing structures/relationships or to make adjustments in reaction to emerging turbulences in trading business environment, as current established structures are expected to be affected by increasing volatility and changing price structures. The decision-maker considers that such exogenous aspects could further extend the SC Intelligence Wizard: the (effect of the) political environment and the financial markets is perhaps missing here, and the higher macroeconomic elements and also the general trade agreements in countries (...) it's changing more and is more hazardous.

6.3.2 Azadora

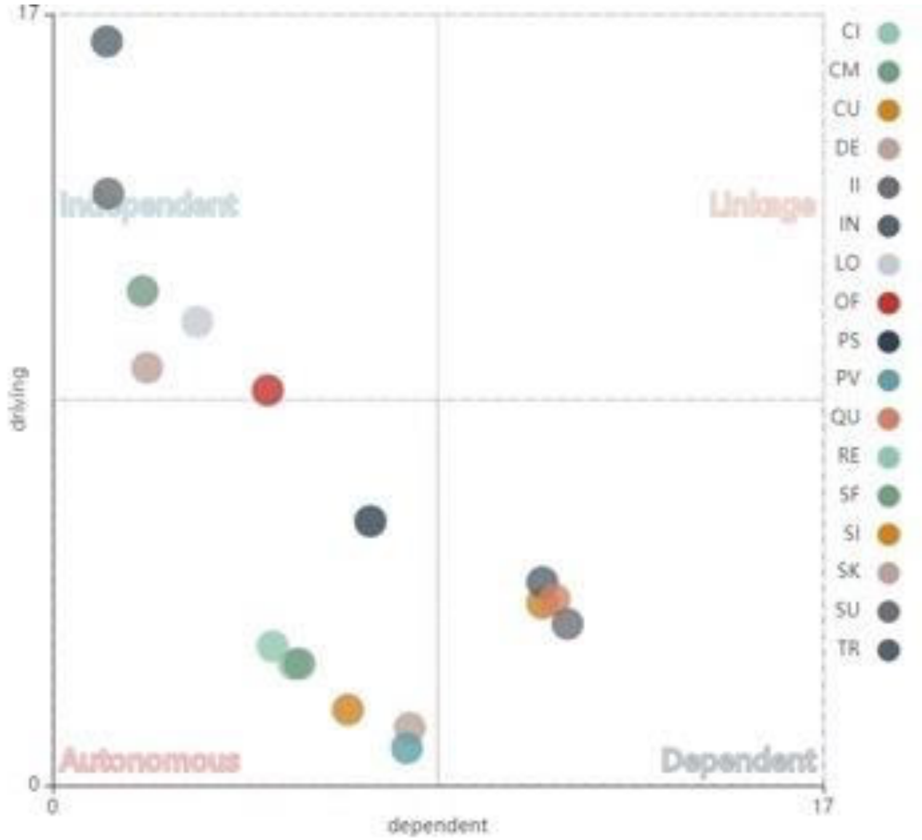
Business model: garment production (Azadora - local fashion outerwear). Size: medium. Product focus: fashion small series. Focus: 100%. Sourcing model: internal. Stage of small series production implementation: planning/development (B2C).

Azadora has established production of fashion outerwear in small order sizes, in a wide variety, with a range of less than 100 to 300 per model. Generally, its maximum total order is about 1000 pieces. Traditional artisanal and innovative production technologies characterize Azadora's flexible full-package solutions, which benefit from close contact with customers (B2B) and suppliers, as well as quality management certification. Currently it is planning to offer similar products to end-customers as a production on-demand concept, through the development of its own brand.

For this customer demand-driven production, Azadora also plans improvements to use collected data, e.g., automatically generated by advanced production technologies, and monitor production and the supply chain, by extending the focus beyond warehousing.

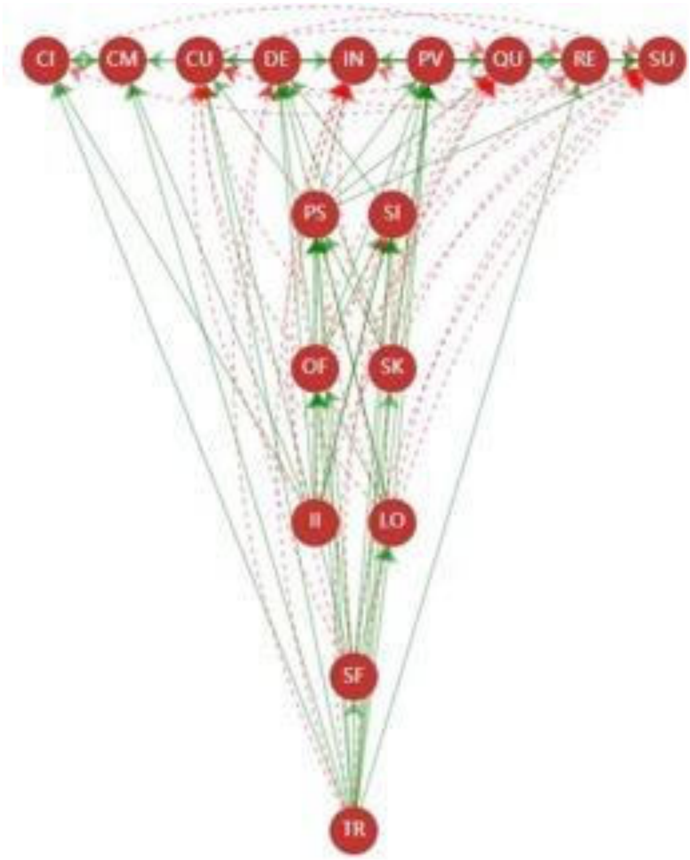
Additionally, Azadora also plans to use web services to sell directly to consumer for its made-to- order (MTO) production. Though cost is the main challenge to enhance material sustainability, to date sustainability has been less within their control due to the power of the brand in established relationships. However, this has the opportunity to be extended via direct digital sales and associated interactions with customers. On the supplier side, relationships benefit from personal connections made locally/regionally.

Table 5. Supply chain Intelligence I (Azadora).



Autonomous	CI CM DE PS PV RE SI
Independent	II LO OF SF SK TR
Dependent	CU IN QU SU
Linkage	

Table 6. Supply chain Intelligence II (Azadora).



6.3.2.1 Validation

The interrelationships shown in SC Intelligence I and SC Intelligence II indicate the lower degree of interactions among the SNCC aspects when configuring Azadora's offering of small series production. Specifically, the SC Intelligence model I shows a presence of a number of autonomous aspects that do not impact other ones in a significant way regarding the configuration of Azadora's production system.

The key drivers show the importance of trust from the manufacturer perspective, regarding sourcing and customer relationships, however this is limited by the low level of control had, beyond the internal production system. Key outcomes include development of new end-customer relationships to offer the same trust and quality as already offered to brands, as well as the ability to offer innovative products, in high variety with consistently high quality. The adjustment to one-piece production on- demand is likely to change these dynamics through an increase in control of the various aspects. In this way, the internal integration will play a central role with location benefits, resulting in the crucial outcomes of the system including customer-facing issues and associated capabilities (customization, delivery, quality, sustainability, innovation). While trust is driving internal knowledge and flexible specialization, as well as constraining sourcing flexibility, the new focus on products for end-customers will likely change configurations. Specifically, regarding material sourcing, the producer needs support for selecting suppliers in accordance with product types/characteristics, as well as the existing levels of structural flexibility, i.e., the number of trusted fabric suppliers. While the company's products/processes are well documented, the available data is not yet used, indicating the opportunity to further develop internal integration systems. The key consultant supporting the decision-makers specifically states that they are more interested in the supply chain and production management because they do not (yet) have a brand; they are interested in optimising their own work, (...) specifically through the optimization of supplier selection for a specific garment, based on their requirements introduced in the system, and their database of suppliers.

6.3.3 Kuvera

Business model: sportswear branded manufacturer/retailer (Kuvera - global sportswear). Size: large Product focus: hybrid (functional/fashion). Small series focus: 10% (increasing). Sourcing model: external. Stage of small series production implementation: planning/development.

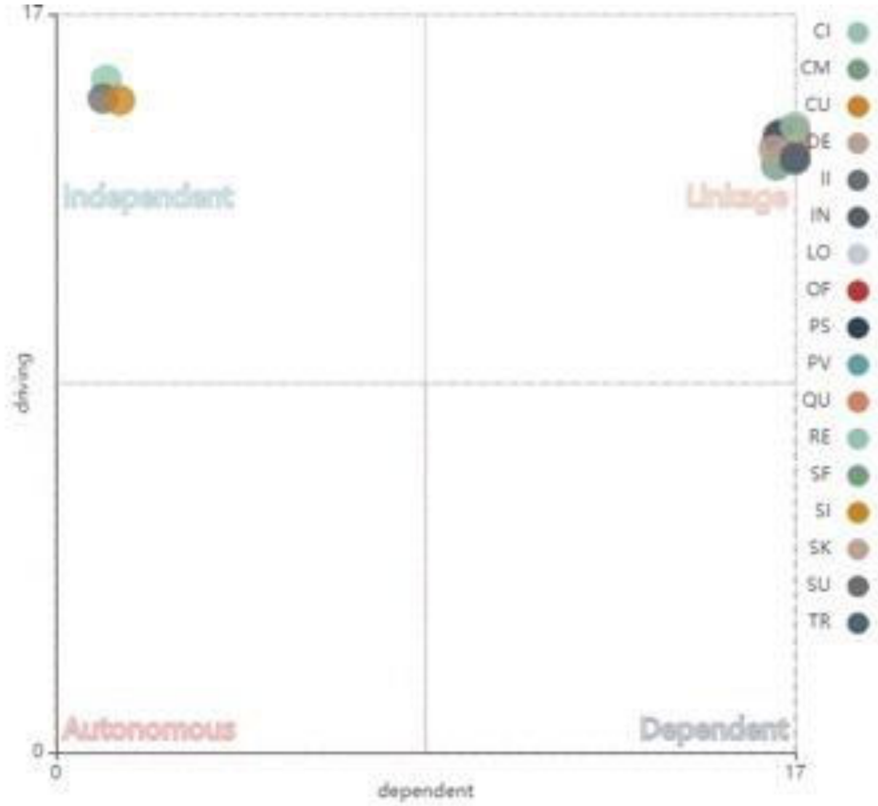
Kuvera is focusing on highly technical sportswear, such as sportswear (e.g., for swimming), however currently only laboratory production for special projects. These niche/highly technical products particularly for swimming are to be offered to a wider group of customers, with development of sourcing nearby (e.g., Italy). Company knowledge gained from co-creating the products with users for their specific requirements is of key importance.

These small series products will be characterized by a high level of personalization, in contrast to standard and fashion products offered, specifically, including customization for body dimensions (including for physiological issues) i.e. made-to-measure, fabrics, and use environment.

The products will be sold in Jaked (group's sportive brand) stores (direct customer) and e-commerce. The company has invested in a 3D body scanner but needs to "problem solve" getting these measurements from customers through both channels. This is particularly challenging for e-commerce, and the key point of innovation is this digital interaction with end customers relate to digital visualization and customization experiences.

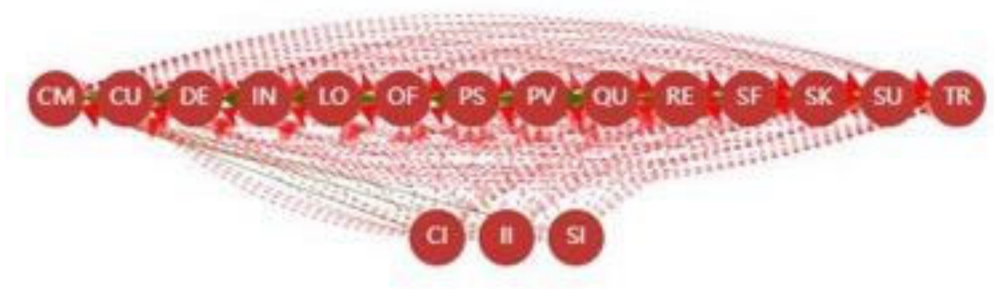
For each product/material the company needs at least two suppliers specialized in 3D knitting or alternative knitting and garment construction methods. These suppliers must be local/regional partners with willingness to integrate digitally and offer full-package solutions.

Table 7. Supply chain Intelligence I (Kuvera).



Autonomous	
Independent	CI II SI
Dependent	
Linkage	CM CU DE IN LO OF PS PV QU RE SF SK SU TR

Table 8. Supply chain Intelligence II (Kuvera).



6.3.3.1 Validation

The high levels of interrelationships shown in the linkage aspects in SC Intelligence I and the top level of SC Intelligence II indicate the complexities related to the transition to small series production, specifically for Kuvera (more specifically for Jaked group's sportive brand), regarding the development of highly technical products, with extreme fit and performance customization.

These new products are to be built upon existing competences, while at the same time must be developed collaboratively with "new" specialized suppliers. This requires identification of appropriate suppliers, with capabilities to produce specialized products (by balancing price, quality and speed), that are willing to take on the sourcing of special materials.

Additionally, the variety of materials required to produce these highly technical products, demand a larger number of suppliers, which in turn requires support for strategically selecting suppliers, and development of the company's integration systems to monitor materials and capacity.

Furthermore, customer interactions must be designed to get the information required (related to product functions and fit). This is the key point of innovation demanded from digital partners or an IT service provider to facilitate the customer interaction (customization/visualization) process.

In line with balancing these issues, Kuvera also validated the benefit of considering the four interacting elements of the SNCC model in relation to the goals of supplier selection - specifically cost, quality, and speed with their expansion into customization. The decision-maker specifically states that it is a very good plan that they can follow to implement this new process. Just divided by products, operation, relationships, structure, and first of all relationships. First of all, they need to fix relationship collaboration, cooperation, visibility, trust etc. This is first of all to design the vender list.

6.3.4 Beste

Business model: garment/fabric manufacturer (Beste - vertically production of functional fashion and outwear). Size: medium. Product focus: hybrid (fashion/functional). Small series focus: 100%. Sourcing model: internal. Stage of small series production implementation: established/experimentation.

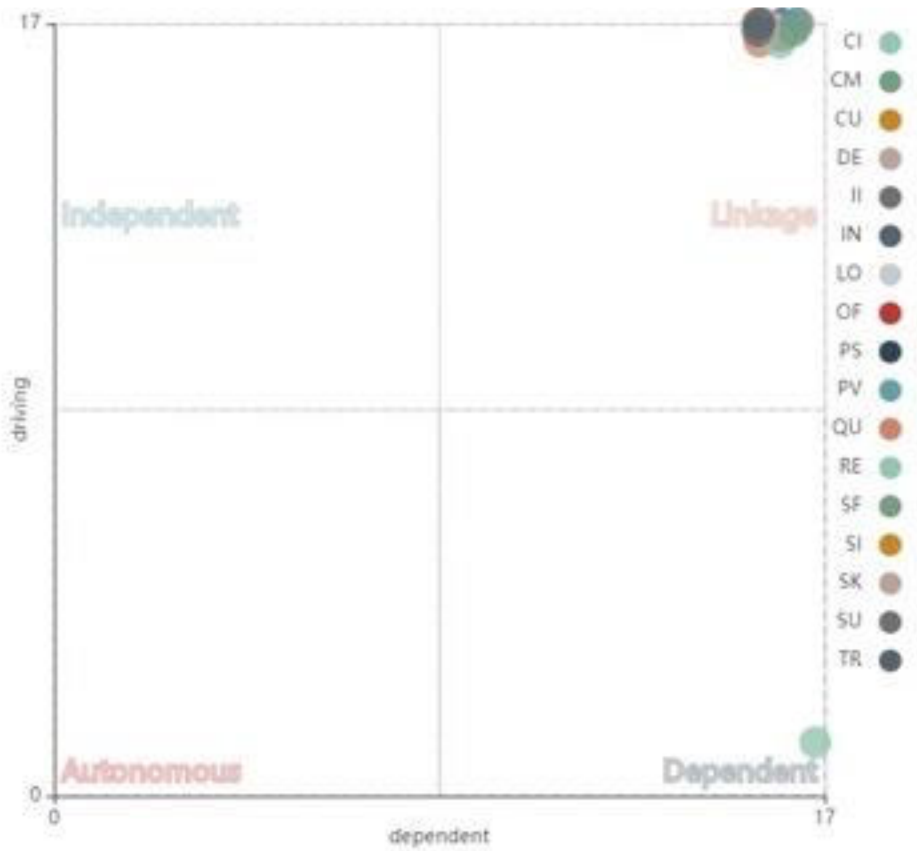
Beste is a globally dispersed and vertically integrated company with significant focus on innovative and sustainable fabric production, and fashionable, high-tech apparel products.

The focus is on producing highly technical and complex garments, offered in a mix of make-to-order (MTO) and design-to-order (DTO) for its own brand (Monobi) directly or co-branded with B2B customers. Production lots around 1000 pieces, with experimentation down to single piece fashion.

Key features of its production system are extensive digital tracking and internal integration (especially for fabric) with greige produced in Asia and finishing conducted in Italy. However, integration not as well established between the fabric and apparel departments/divisions.

The apparel brand focuses on complex fashionable/functional products which are shaped by internal and external fabrics and process technologies. The products are increasingly including recycled or sustainable materials, which can be enabled by internal development, but can be challenging due to limited willingness of accessory suppliers to collaborate and innovate. Internal product/process development includes experimentation with personalization, particularly focused on colour customization of classic products for end-customers. This approach is based on competence related to fabric production and finishing (through vertical integration), and newly developed digital design technologies, hardware and software for exact colour matching in the dyeing process.

Table 9. Supply chain Intelligence I (Beste).



Autonomous	
Independent	
Dependent	CI
Linkage	CM CU DE II IN LO OF PS PV QU RE SF SI SK SU TR

Table 10. Supply chain Intelligence II (Beste).

6.3.4.1 Validation

The high levels of interrelationships shown in the linkage aspects in SC Intelligence I and in level 2 of SC Intelligence II indicate the complexities related to small series production and specifically for expansion to one-piece production of highly technical products, with eventual customization by focusing on higher integration with end-consumer.

The key outcome highlighted is thus development of customer interaction, in order to better communicate the brand's complex products. While a large set of interrelated SNCC aspects influence customer integration in Beste's supply chain, the dominant role of these interactions is due to the higher control resulting from vertical integration. However, internal integration is not at a high level between departments, and the complexity of the product provides additional challenges for customer-facing communication. Thus, in order to increase focus on MTO/customized production of the brand's complex fashionable and functional garments, internal integration must be improved to align diverse functions and divisions, due to their diverse priorities. This integration should focus on supporting the balance of various interacting priorities such as quality, delivery, innovation and sustainability, and facilitate external communication.

Additionally, in order to meet customer demands for greater sustainability with product functionality, supplier relationships could be crucial, although challenging especially due to limitations of willingness of the accessories suppliers to participate in collaborative development and innovation. Beste foresees material technology changes can shape the overall structure of sourcing, depending on the requirements for external and internal technologies; thus, the company is focused on the control they have to develop internal production competence. The key consultant supporting the decision-makers specifically states that the (crucial point and) challenge is the communication and using different priorities and different language (…) maybe we are speaking about the same problem, but with a different language. The product will benefit from being introduced with sort of digital models of the business model, as you can transfer this information that is more difficult in a shop (especially virtual - e-shop), through a software.

7 Bibliographic References

[1] Pfohl, H.-C., B. Yahsi, and T. Kurnaz, The Impact of Industry 4.0 on the Supply Chain, 2015.