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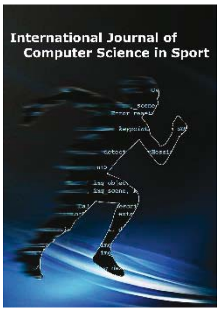

A Concept for Club Information Systems (CIS) - An Example for Applied Sports Informatics

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Abstract

In professional sports clubs, the growing number of individual IT-systems increases the need for central information systems. Various solutions from different suppliers lead to a fragmented situation in sports. Therefore, a standardized and independent general concept for a club information systems (CIS) is necessary. Due to the different areas involved, an interdisciplinary approach is required, which can be provided by sports informatics. The purpose of this paper is the development of a general and sports informatics driven concept for a CIS, using methods and models of existing areas, especially business intelligence (BI). Software engineering provides general methods and models. Business intelligence addresses similar problems in industry. Therefore, existing best practice models are examined and adapted for sport. From sports science, especially training systems and information systems in sports are considered. Practical relevance is illustrated by an example of Liverpool FC. Based on these areas, the requirements for a CIS are derived, and an architectural concept with its different components is designed and explained. To better understand the practical challenges, a participatory observation was conducted during years of working in sports clubs. This paper provides a new sports informatics approach to the general design and architecture of a CIS using best practice models from BI. It illustrates the complexity of this interdisciplinary topic and the relevance of a sports informatics approach. This paper is meant as a conceptional starting point and shows the need for further work in this field.

KEYWORDS: SPORTS INFORMATION SYSTEMS, CLUB INFORMATION SYSTEMS, BUSINESS INTELLIGENCE, SPORTS INFORMATICS, TEAM SPORTS

Introduction

In professional sports clubs, the need for a central information system has grown in recent years due to the increasing number of different information technology (IT) systems in each department that generate huge amounts of decentralized data. A growing number of experts have complemented existing staff and need access to all relevant data. In industry, similar problems are addressed by the field of business intelligence (BI), a subsection of business informatics. BI has developed powerful systems for merging data from different sources and generating information for decision-makers. The idea of this paper is to develop a general concept for club information systems (CIS), by using methods and models of existing areas, e.g. BI. In this way, a concept is created that reflects the needs of sports practice and points out, which CIS design could be most appropriate for the setting. Moreover, the suggested design is also meant for providing a database to use methods of data science, e.g. advanced analytics, visual analytics or machine learning in the specific context of sport clubs. This could generate new insights and reveal patterns and correlations, especially within the joint data of previously unconnected systems.

Various suppliers have recognized this need for CIS and now offer their products to clubs or individual departments. The design of such CIS remains a challenge because many different areas are involved: Software engineering, business intelligence, training and exercise science, and sports practice. The problem in sports clubs, however, is that very traditional structures still predominate and especially in the sports department hardly any employee has a native IT background. Besides, there is a very reluctant attitude towards sharing and passing on information.

The approach of this paper is to involve sports informatics or computer science in sports (Link & Lames, 2014) to meet the interdisciplinary and the sport-specific demands posed by designing appropriate CIS. The need for such a novel approach becomes obvious as existing information systems for sports clubs are typically limited to a few fields in the clubs and were primarily developed from an IT perspective or existing software products were simply applied in sports clubs. No comprehensive and sports informatics driven approach was taken explicitly so far.

There is only very little literature on information systems in sports, which also follow very different approaches, e.g. providing specific concepts for a certain subsection like medical data, giving a very general framework but without a specific design concept or investigating the information needs of the staff. In sports informatics, Lames (1997) addressed the problem of different systems and isolated information in sports clubs and introduced the term information system in sports. In Schnabel, Harre, and Krug (2014) a theoretical draft of a training system was presented. For the first time, Blobel (2009) developed the basic idea of making data from various sources and areas centrally available to sports clubs with the help of business intelligence systems. Blobel and Lames (2015) then presented the idea of an information system for top-level clubs, with proposals for a structure and a prototype analysis software for performance diagnostics data, based on the BI software QlikView. They then further developed this concept into an information system focusing on medical data and healthy reference patterns (Blobel & Lames, 2018). Rein and Memmert (2016) presented the idea of combining various data sources for tactical analysis and refer to the medical health sector, which is facing similar problems. They also presented an architecture proposal for this specific case. A work by Shah, Kretzer, and Mädche (2015) presented the development of a game analytics system for professional sports teams, with a prototype, and in cooperation with three football teams in different competitions and a software manufacturer. They worked with interviews and questionnaires.

The overall objective of the present work is to design a general architectural concept for central CIS that focuses on sports practice and data analysis. Sports informatics, or computer science in sports, forms the interdisciplinary approach to identify and include the relevant academic and practical fields to apply them to the specific context of sports clubs. Accordingly, the practical references to software engineering, business intelligence, and sports science fundamentals are established. Sports science provides fundamental theoretical models that are considered and adopted to this work and are additionally described by a practical example of Liverpool FC. The proposed architecture is based on existing technologies and legacy systems and integrates them into a comprehensive solution tailored for sports clubs. The architecture is generic and independent of certain providers to best meet the existing needs of sports clubs. A further characteristic of this work is the sports practical point of view addressing also organizational aspects and human factors (Avison & Elliot, 2006). To fully understand the practical challenges, practical experiences were collected in the form of participating observation by working in sports clubs.

The objectives of this study are threefold: Objective 1 is a brief presentation of the areas involved and a description of their major contributions for the development of a CIS. Objective 2 is the analysis of a typical club structure and the derivation of the key requirements for a CIS. Objective 3 is to provide a general architectural and design concept for a CIS and to give examples of its practical functioning.

Accordingly, this paper is structured as follows: First, an overview is given on software engineering, business intelligence, and training and information systems in sport with a practical example. The main section presents details of the developed design concept of a CIS. A final section depicts typical problems from practical experiences with introducing CIS in professional football clubs.

Methods of software engineering for system analysis

Software engineering describes the systematic scientific and technological approach for designing, implementing, testing and documentation of software and the development of methods behind that (Institute of Electrical and Electronics Engineers (IEEE), 2017). The approach of this work is based on software-intensive systems, because its main character is largely defined by software (Institute of Electrical and Electronics Engineers (IEEE), 2017; Vogel, Arnold, Chughtai, & Kehrer, 2011). Software engineering focusses on the process of software development (Foster, 2014), and it covers the research on software systems (Taylor, 2019). Different development models and strategies for software development are known, but generally, they follow similar phases. In this paper, the development phases of Foster (2014) are used and adapted to the requirements of a CIS.

In the first phase, investigation and analysis, the necessary system requirements are deduced from the organizational requirements (Vogel et al., 2011). This demands an individual analysis of the organization with the background and characteristics of the specific sport discipline. Methods and knowledge of training and exercise science are adopted to investigate the particular situation at sports clubs (see Section 4). The second phase is design and architecture. Design is described as "process of defining the software architecture, components, modules, interfaces, and data for a software system to satisfy specified requirements" (Institute of Electrical and Electronics Engineers (IEEE), 2017, p. 129). While the design of such a system is more general, the architecture, as a part of it determines "fundamental concepts or properties of a system in its environment embodied in its elements, relationships, and in the principles of its design and evolution" (Institute of Electrical and Electronics Engineers (IEEE), 2017, p. 26; Taylor, 2019). These are fundamental decisions that cannot be changed later, or only with great difficulty. The correct architecture is crucial when systems are constructed from many components (Garlan & Shaw, 1993). As a general CIS concept is pursued here, this work focuses primarily on these first two phases. Subsequent phases, such as development and implementation and deployment and management, are only marginally addressed in this paper. Nevertheless, they have to be considered in the first two phases, where fundamental choices have to be made which have an impact on later phases and cannot be adapted, or can only be adapted with difficulty. CIS typically have high complexity due to the demand for integrating existing components and need high flexibility for adapting new components. For that reason, a model driven architecture (MDA) with different levels of abstraction was chosen. The computation independent model (CIM), as a domain model, provides a high level of abstraction and represents the organizational perspective within sports clubs, independent of the technical implementation. Based on this, the platform independent model (PIM) is a logical system model, which already takes into account the interaction of the system components and also has a technological reference (Object Management Group (OMG), 2014). This level of abstraction provides the basis for the CIS concept developed in this paper. Within this level, the PIM was additionally divided into different hierarchical layers (Garlan & Shaw, 1993), to structure the complex system into different components, and show, how they interact (Institute of Electrical and Electronics Engineers (IEEE), 2017; Vogel et al., 2011). A future step would be the transformation of the PIM into a platform specific model (PSM). Such an implementation model, based on a specific technology or platform, could be developed and described as a use case for a specific club. In the next section, this concept will be described in more detail in the context of business intelligence systems.

Business Intelligence

Business intelligence (BI) is the field in business that concerns the information support and data analysis tools for the management. Already in the sixties, so-called decision support systems (DSS) came up, which should support managers by the use of computers and related IT (Power, 2008). In the 90s, the term business intelligence was developed within the practical business environment, but different definitions could be found (Devine, Srinivasan, & Zaman, 2004; Popovič, Hackney, Coelho, & Jaklič, 2012). Some definitions limit a BI system primarily on the support of the top management with relevant information for their decision making (Bucher, Gericke, & Sigg, 2009; Devine et al., 2004). Others understand it broader and involve the entire integrated management infrastructure (Kemper, Rausch, & Baars, 2013). In this work, BI is meant in its broader sense, not only focusing analysis and presentation of data, but also data processing and storage, including all components of integrated infrastructure to support the decision-makers (Kemper, Baars, & Mehanna, 2010).

Sports clubs are organizations that are very similar to business companies (Link, 2018) but do also have very specific organizational structures, internal functions, and data structures. In the following, concepts of BI will be used and transferred to the specific conditions at sports clubs. One specific MDA for BI systems on a higher level of abstraction has been developed by Baars & Kemper (2008). Their multi-layer framework separates the complex BI system into different layers organized in a hierarchy (Institute of Electrical and Electronics Engineers (IEEE), 2017). There is always just one layer at each level of the hierarchy and each layer only interacts with the superior/subordinate layer. These layers exchange data but interpret that data only partially identically (Garlan & Shaw, 1993; Institute of Electrical and Electronics Engineers (IEEE), 2017).

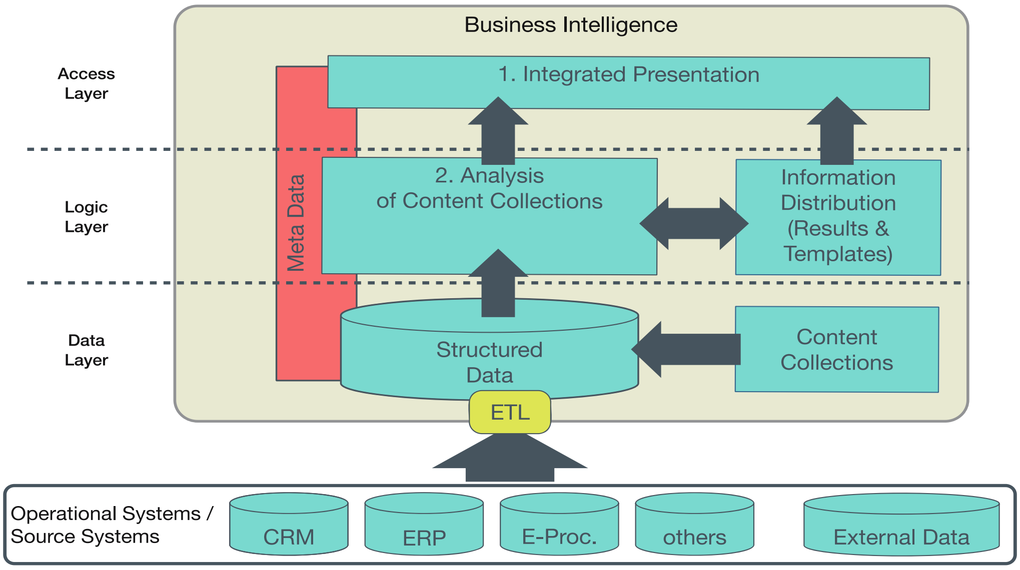

Figure 1. Three-layer architecture of a BI-system (modified from Baars & Kemper, 2008)

Figure 1 shows the BI system as three-layer architecture, set up on the operational/source systems. This highlights the benefit of such an architecture because the source systems persist independently of the BI system. The data of these systems are loaded into the BI system into the data layer. The extraction transformation load (ETL) transforms the data into the required format and quality. This also includes data filtering, which means not all data is transferred from the source systems into the BI system. An additional way to increase the automation of data exchange is the definition of fixed standards for the exchange of structured data between different systems in sports, such as electronic data interchange (EDI). This reduces the number of interfaces and the complexity of data manipulation (Häckelmann, Petzold, & Strahringer, 2000). This standard can be used in the application programming interface (API) of the different systems. The logic layer contains two components: Systems for data analysis and information distribution to analyze data from the data layer and generate and distribute relevant information. The access layer unifies all the relevant content and functions from the logic layer and provides them in a user-specific and easily accessible way (Baars & Kemper, 2008).

The following characteristics of the three-layer architecture are relevant for this work:

(1) Accessing data from existing source systems without replacing them.
(2) Import of all relevant data from the decentralized source systems into one central system.
(3) Preparation of data by specific analyses using particularly up-to-date analytical methods.
(4) User-specific provision of information to support users in a personalized and appropriate way.

In the past, the design of BI systems was primarily technologically driven, neglecting the business process perspective (Bucher & Dinter, 2008). Modern solutions focus the business models first and then transfer it into architecture (Meertens et al., 2012). This helps to identify the social and organizational challenges and integrate them into organizational structure (Baldassarre et al., 2020). These models can also be used for the development and successful implementation of a BI system because it is crucial to consider the existing organizational processes and implement them into the development. The IT must be adapted to the existing processes at the organization, but also provide and determine standardized (best practice) processes to the organization.

Training Systems and Information Systems in Sport

In theoretical concepts of training and exercise science traditionally complexity and dynamics of sports training are accounted for (Hohmann, Lames, & Letzelter, 2014; Schnabel et al., 2014). Training systems take a comprehensive and systematic view of sports training and consider the fundamental and interdependent processes and elements involved. This includes a variety of interacting elements within the different training phases: Planning (training concept), execution (training performance) and evaluation (analysis and assessment) of training and competition. Training systems include athletes (acting) and coaches (leading) as participants as well as a variety of elements, such as medical and physiotherapeutic services. The constant interaction of the structure and function of a sports training process requires a profound knowledge of the training structure. The training structure defines the structure and inner context of the essential elements of the training process, their lawlike relationship with each other, their interaction (in the sense of a process structure) and their succession (phases). Thus, the training structure depends on the type of sport (Schnabel et al., 2014).

It must be mentioned though, that these models of training systems in standard textbooks of training and exercise science relate primarily to energetically determined sports such as track and field and swimming. Training systems in team sports such as football with their complex determination are even more useful. Moreover, football is a team sport in which the interaction of different players with the tactics involved brings an additional dimension of complexity.

The traditional notion of training systems is primarily meant as abstract systematics and by no means technologically as a design for supporting software systems. These aspects were only recently introduced to support training (Baca, 2015). Considering the participants involved in modern training systems the model of Schnabel et al. (2014) needs to be updated. Nowadays, not only many athletes are participating, but also the number of coaches has grown and a variety of additional experts are involved (psychologists, nutritionists, game analysts, ...).

Moreover, in all sub-areas involved scientific knowledge has increased in the past, giving further support to the necessity of an appropriate information system (Lames, 1997).

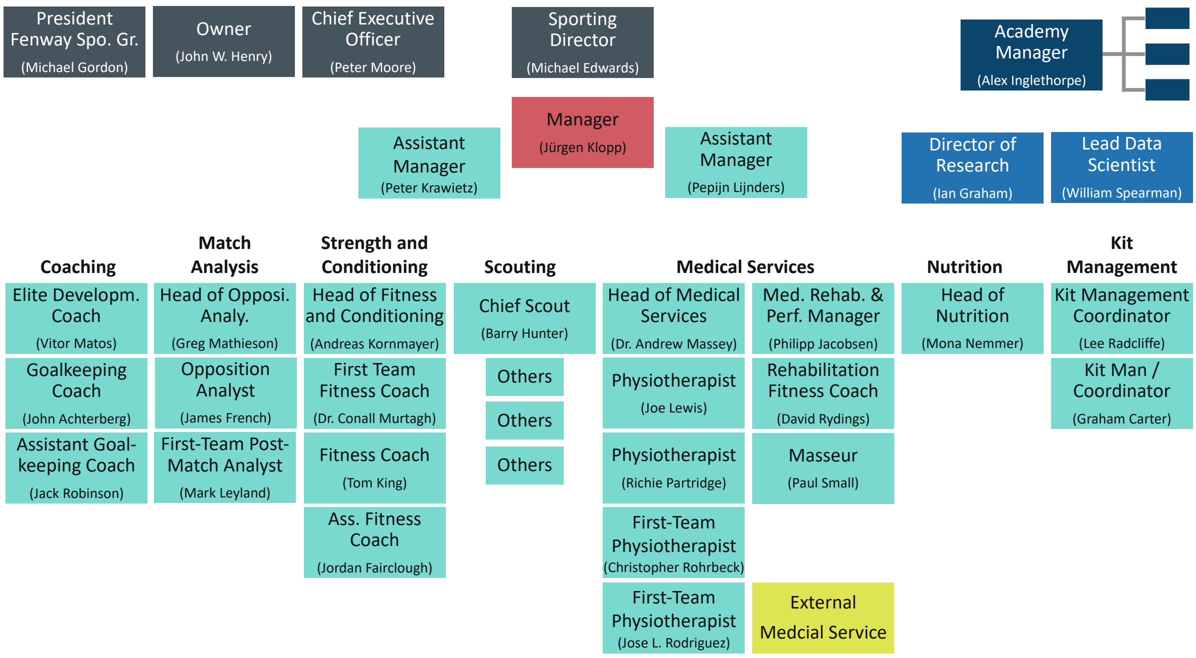

Figure 2. Structure of users in a training system at FC Liverpool (Liverpool FC, n.d.).

Due to the number of different participants in modern training systems with specific information, the head coach is increasingly confronted with the organization and integration of the experts. These demands result in the need for an information system that allows the head coach to effectively meet these demands.

As an example, Figure 2 shows the club structure of Liverpool FC staff at the end of the 2018/2019 season. In this structure, the manager (= head coach) has a central position where various (key-)information merges. Each department has different experts who use specific software systems, with their data and information. Depending on the size of the department, specific sub-flows of information exists. E.g. in scouting, scouts who work internally and externally, and also nationally and internationally, which requires an own information system. There is not only information flow within a department, but also the exchange with other departments. For example, the medical department has internal exchange with strength and conditioning, and nutrition, but also externally with external medical services. The youth academy with all its youth teams forms an organization within the club and is presented by the academy manager, who manages the exchange with the professional team. There is also an exchange and influence by management and data analysts who interact with the experts and the athletes. This shows the increased complexity of modern football-specific training systems and the need for IT support to accomplish this.

Concept of club information systems (CIS)

This section aims to use the different approaches described in the previous sections to develop a specific concept for a CIS in sports clubs. After determining the organizational requirements in order to derive the system requirements of a CIS, the CIS architecture is presented and explained.

Organizational requirements and system requirements

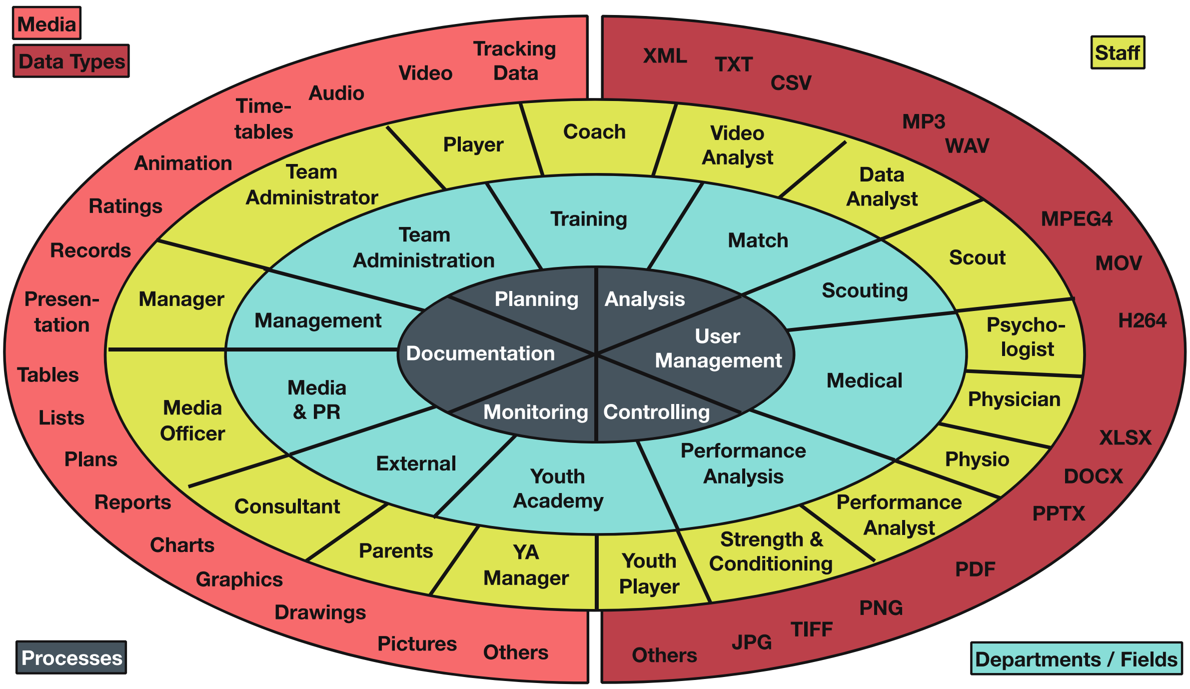

Figure 3. Structured concentric model in four level of abstraction for a football club.

As described in Section 2, at "investigation and analysis", the organizational requirements have to be determined to illustrate the specific structures and processes within the club. For this purpose, a concentric structural model was developed as part of this work (Figure 3). This computation independent model (CIM) helps to determine and illustrate the special structures of sports clubs. Based on that the system requirements can be deduced and the design concept for a CIS can be developed. At the center of the concentric model, the main characteristics of such a CIS are presented. Each other circle becomes more and more specific to the club structure until it lists the individual types of media and file formats. In this way, different perspectives can be taken, analyzed, and illustrated to design the CIS. The second circle shows the division of different fields in the club instead of over-arching departments. The reason for this is, that two departments (e.g. medical and strength and conditioning) could need data from the same source system (e.g. tracking system). By the division into fields, a data or system-specific perspective is taken and a clear differentiation is possible (e.g. tracking data are now part of the area performance analysis and the medical and strength & conditioning departments then access it). Departments also depend on club structure and could be different at each club. The third circle shows the different user profiles at a sports club, based on the role profiles within a training system shown in Figure 2. This is relevant for access, individual presentation, and data governance. The fourth circle is split into two parts. The right side lists the specific kind of data and on the left side the media. This is important for the technical structure of a CIS.

Table 1. Key organizational requirements of sports clubs lead to system requirements for the CIS.

Organizational Requirements Football Club	System Requirements CIS
Many different sources Data Import Individual data profiles Separated data	- Combine data of different sources - Centralized data - Interface for data sources
A lot of traveling Decentralized access	Ubiquitous access
Athletes in different groups (shifting) Different staff member Different departments	- Right governance - Different user profiles
Changing structures / needs Not every dep. is ready Existing systems at the club	- Modular - License model - Flexible system / architecture - Adjustments
User specific information	User specific / flex. customizable UI
Sport specific needs	Open for other systems
Better insights / understanding of data Deeper analysis	Data Science
Sensitive data	Security

This concentric model shown in Figure 3 supports the systematic investigation of the individual levels related to the processes within the club to determine the organizational requirements, listed in Table 1. The organizational requirements were determined based on practical experience working in clubs and questionnaire-based interviews with staff (n=16, see Section 6). From the organizational requirements, the system requirements of the CIS are derived, shown in the right column of Table 1. A rather high level of abstraction was consciously chosen without mentioning technical solutions. For example, the need for decentralized access was named ubiquitous and not cloud-based services because this term is only a current technical solution and the CIS concept presented here should be more general.

CIS Architecture

A model driven architecture (MDA), with a higher level of abstraction at an organizational level, was chosen to develop a general design concept for a CIS (Object Management Group (OMG), 2014; Vogel et al., 2011). This can be applied to different club structures and then individually adapted. As described in Section 3 a layer-based architecture divides the overall complexity into individual hierarchical layers, which can then be edited separately (Garlan & Shaw, 1993). Figure 4 shows a suggestion for the MDA of a CIS based on the three-layer architecture for BI systems (see Figure 1) by Baars and Kemper (2008).

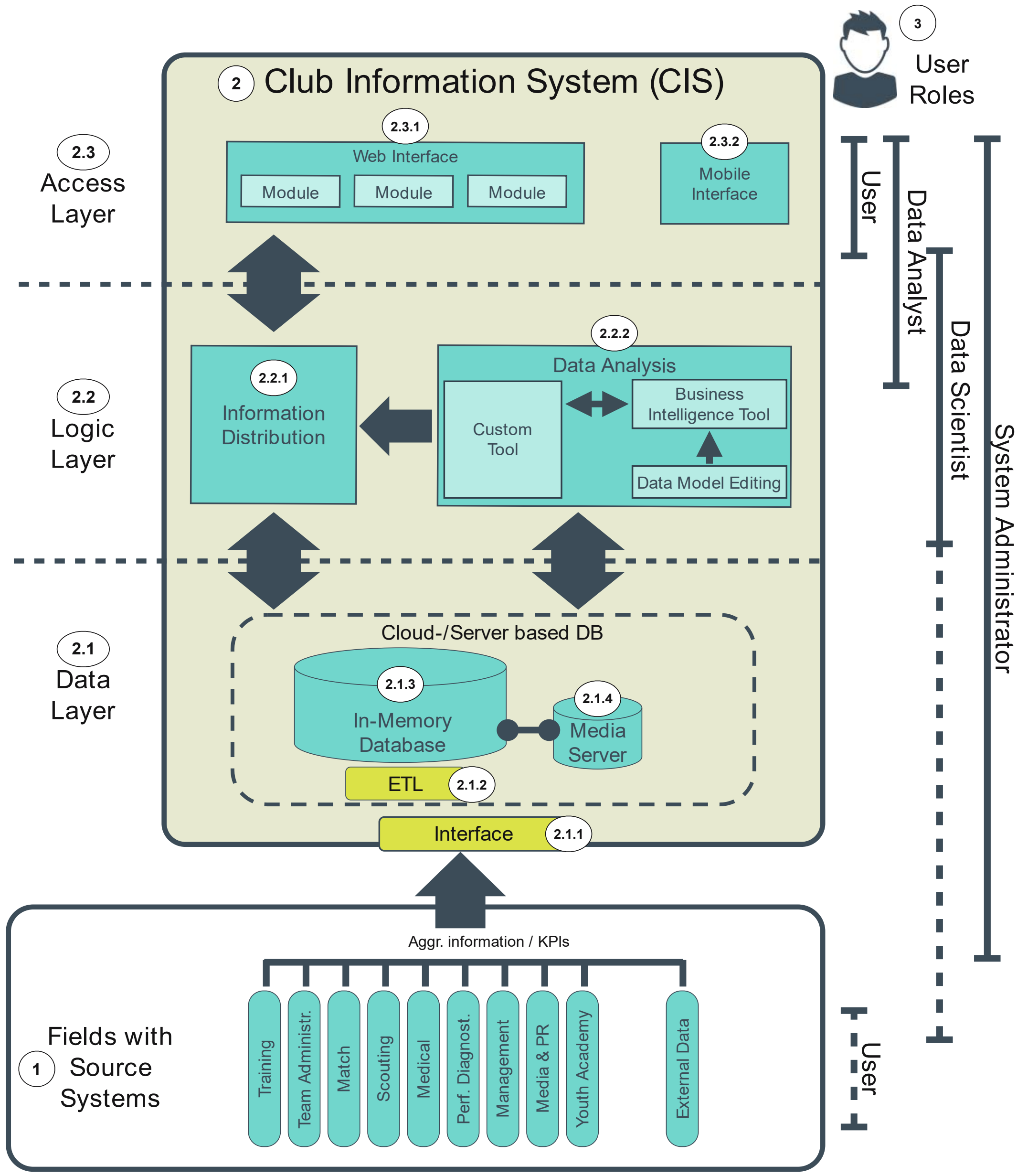

Figure 4. Three-layer architecture of CIS with different user perspectives.

Figure 4 shows the CIS architecture developed in this paper based on the general structure of football clubs (Figure 3) and the defined system requirements (Table 1). Three major parts are distinguished: The *source systems* (1), the actual *CIS* (2), and the *user roles* (3). These main areas consist of different components and are described in detail below. Finally, this section points out the modular structure as an essential feature of the CIS and recommends an open-source policy.

(1) Source Systems: Structure and integration

The aforementioned advantage (Section 3) of accessing the existing source systems instead of replacing them, and importing the data into a central superordinate data store, is also used here. Depending on which systems already exist in a club, these are not replaced but could be integrated into the CIS. Thus, the CIS remains flexible and can be built on an existing infrastructure, or the source systems can be replaced as better technology enters the market or contract terms end. This is described as a best of breed (BoB) approach, whereby the best standard software from different providers is integrated (Light, Holland, & Wills, 2001). It should not necessarily transfer all the data of the *source systems* (1) into the CIS since this form of granularity provides no added value for the respective user and the amount of raw data often is very large (Baca, 2015). Thus, it may be useful to reduce the amount of data and only aggregated data and *key performance indicators* (KPIs) to take over into the CIS (Dabnichki & Miyaji, 2015).

An example is positional data from tracking systems for match analysis. The head coach needs meaningful information in the form of KPIs and aggregated data on specific match events, which he defines in advance with the game analyst. However, the detailed high-frequency X/Y coordinates, which require a lot of resources (Linke, Link, & Lames, 2018), may not provide added value to the head coach. But to generate this specific information, the game analyst needs access to the detailed tracking data. This would mean, that only aggregated data and KPIs obtained from the detailed data are provided to the head coach (and other staff) and become elements of the CIS. The 'raw data' remain in the corresponding source system. For the medical department and the strength and conditioning coaches, these tracking data are important for the player load management. Therefore they require training data from their own tracking system and also match data, which are usually provided by a central provider. These are then combined with heart rate data from a heart rate monitor, the rate of perceived exertion (RPE) via smartphone, additional systems from the gym, and individual thresholds and laboratory data. In this case, there are already about seven different systems/sources that partly overlap with other departments (e.g. game analysis) but require a different granularity and view of data. Besides, individual systems are also replaced, eliminated, or added from time to time.

(2) CIS: Three-layer architecture

On top of the *source systems* (1), the *data layer* (2.1) of the actual *CIS* (2) is set up. The data are loaded from the different *source systems* (1) into the centralized *database* (2.1.3) via a specific *interface* (2.1.1). The *extraction transformation load* (*ETL)* process (2.1.2) ensures the standardized quality and format of the data, the data model and the data structure. As usual with modern BI systems, an in-memory database is recommended to increase the performance and flexibility of the queries. To avoid loading the centralized *database* (2.1.3) with memory-intensive media data and reduce its performance, it is recommended to store these data within a separate *media-server* (2.1.4), optimized for media data. For ubiquitous access, a server-based database is suggested, so that users can access it from outside the club area. These services provide modern and professional infrastructure, high security standards, are scalable, and offer optimized solutions, such as for media data. This provides high flexibility and the system can grow with the needs of the club (Dashofy, 2019). There are also different problems of cloud services, that have to be considered and be discussed (Taherkordi, Zahid, Verginadis, & Horn, 2018). However, a disadvantage for clubs is that the servers and in this way also data are outside of the club area. In addition, the costs of cloud services can rise very quickly with extensive use. At this stage of a PIM, it is too early to determine a particular implementation technology or platform. However, a clear evaluation of a centralized architecture against a cloud-based architecture must be made when the architecture phase of a PSM is reached.

The *logic layer* (2.2) is divided into two components and placed above the data layer. The *information distribution* (2.2.1) collects and processes data from the *data layer* (2.1), converts them into information and forwards it to the next layer. The *data analysis* (2.2.2) component provides ways to do a more in-depth analysis (Baars & Kemper, 2008). Since very complex and advanced algorithms are required, the implementation of powerful external data analysis tools is recommended. *Custom tools* (2.2.2), for example, implemented in programming languages like Python, R or MatLab should be integrated to enable state-of-the-art capabilities for data science. Additionally or alternatively, *BI tools* (e.g. qlik.com, tableau.com or sapanalytics.cloud) can be integrated. Very often interfaces for at least one of the programming languages are already integrated in such BI tools. Again, knowledge of sports informatics is necessary to apply appropriate methods from data science, but also to adequately interpret the findings from a sports science and sports practical view (Rein & Memmert, 2016).

For the use of BI tools, very often a modification of the data model is needed because it differs from the data model of the central database. While the logic of a relational database tries to achieve a very low redundancy of data to increase performance and lower storage, BI systems often require a high level of redundancy to perform specific analyses. To bypass this discrepancy, the *data analysis* component (2.2.2) can provide a data editing tool, that extracts data from the *data layer* (2.1) and converts it into a suitable data model, to develop and perform analyses. The *data analysis* component (2.2.2) can provide *data model editing*, to bypass this discrepancy. This *data editing tool* extracts data from the *data layer* (2.1) and converts it into a suitable data model, to develop and perform analyses.

The results are implemented in the *information distribution* (2.2.1). The great need for meaningful analyses for the staff of the club is considered in the CIS architecture. This architecture enables powerful analysis for profound insights and makes them easily accessible to general users. Data of different systems are well prepared in a central database, where they can be adapted and modeled, but also be accessed with tools for data science, which represent the current state-of-the-art. This aspect is fundamental in this CIS architecture concept and is difficult or impossible to solve later in a final system.

The *access layer* (2.3) involves the *graphical user interface* (GUI) for providing users with the required information from various source systems and contains two components. The *web interface* (2.3.1) is the main *user interface* (UI) to the CIS and presents information from different source systems, depending on their individual job profile (see Figure 3). Because of the low technical background of general users, a user-specific UI and presentation of the required information are crucial (Jayal, McRobert, Oatley, & O'Donoguhe, 2018). This reduces the complexity and lowers the access barriers. As described earlier (source systems), data from different source systems are required to monitor player load from a medical point of view. The following parameters are combined within one screen to the physicians: power load, acceleration, and heart rate from tracking system; inflammation markers from blood samples; RPE of the respective players, which they send via smartphone. Such a CIS enables decision-makers to quickly and independently access the information they need to make their decisions (Alamar, 2013).

The second component at the *access layer* will be the *mobile interface* (2.3.2), to access the CIS via mobile devices like smartphones and tablets. There are different technologies like *mobile web pages* or *mobile apps* to provide information optimized for mobile use. This can be the internal communication within the club and the central access to schedules or analyses. Besides, media files can be sent via messenger or questionnaires, which can then be watched or answered via smartphone. In general, there are two ways in which this can be done and the choice of technology depends on the requirements:

Mobile App: These software applications are designed for the use on mobile devices like tablets or smartphones. However, the development of these apps is complex and a separate application must be programmed for each (mobile) operating system. For this reason, the effort for development and maintenance is high. With mobile apps, it is easier to control what these applications contain. Data can also be stored in the app so that content can be accessed offline.

Mobile Web Page: These small websites present reduced content, optimized for mobile devices. Access happens via browser and depends on the supported browser and not on the operating system. A bookmark of the specific mobile webpage can be stored as an icon on the home screen and creates the impression of an app. Mobile web pages are easier to maintain and new functions are available after refreshing the browser. Content could be changed more easily than with mobile apps. However, the constant need for an internet connection can be problematic because the data is not stored, but workarounds exist. A preset building kit within the CIS could help the club's staff to independently create mobile web pages to provide content.

(3) User roles: Activity and access

On the right side of Figure 4, the typical access areas and access permission of the individual user groups accessing the CIS are shown (3). The general club users (User) act primarily on the access layer. However, it may be necessary for these general users to continue working in the *source systems* (1) for their daily work. Thus, the strength and conditioning coach will continue to operate the tracking system directly on the training field. But for the following analysis, he only needs access via CIS.

The *data analyst* operates primarily on the *access layer* (2.3) and *logic layer* (2.2). This user develops specific analyses in cooperation with the general users and publishes it in the *access layer*. The data scientist acts primarily in the *logic layer* and develops elementary methods and algorithms, which the data analyst then uses for daily operations. This can also lead down to the *source systems* if he has to adjust the recorded or exported data for analyzes. For example, this can be a missing parameter in the tracking data that must also be included in the output so that the strength and conditioning coach can better analyze it (example in Section 6). All these specific activities of data analysts and data scientists may be named sports analytics (Link, 2018). There, methods of data science are applied especially for the requirements of sports science and sports practice. The *system administrator* has access at all layers, down to the *source systems*, to ensure the daily operation of the systems.

It should be mentioned, however, that these role profiles may look different in each club. Depending on individual resources and organizational approaches there may be overlaps of these roles with other roles in the club or even more specialized IT-roles involved.

CIS Architecture principles

Modularity and Scalability

The CIS concept suggested does not consist of a large overall system, but different individual modules that could be integrated and purchased on demand. One recent trend in software design is micro-services. This architectural pattern allows the design of applications as a collection of independent and loosely coupled services and could help to separate such a complex CIS into single modules (Jamshidi, Pahl, Mendonça, Lewis, & Tilkov, 2018; Zimmermann, 2017). With this approach, a club does not need to buy the complete system at once but can start with some specific modules. Later, they can add other modules and the system is growing to an overall system. This could also lead to a higher acceptance because existing solutions do not need to be replaced or double license fees must not be paid. For example, if the physicians at the club already use a system for medical documentation and analysis, but are not yet ready or able to switch to the CIS, the existing system can be used further at first. The medical module at the CIS will not be activated and charged. If the club then decides to use the medical module as well, the existing medical system is connected to the CIS at the *data layer* (2.1) via an *interface* (2.1.1). Here, the *ETL* (2.1.2) process is designed and relevant data are imported into the *central data storage* (2.1.3). The medical *module* will be activated in the *web interface* (2.3.1) of the *access layer* (2.3). For the physicians, this new function now appears in the familiar UI, and they are able to work with it.

Open Source

In general, the use of open-source software for the design and implementation of a CIS is recommended. This creates greater independence from the providers, as the source code is open, it is easier to access with other systems, there is a large community and license costs could be reduced. There is numerous open-source software for different needs that could provide the infrastructure described above (Raymond, 2001). Such a CIS could be fully implemented with open source software, as an example of an information system in geography shows (Kreuzer, Wilde, Terhorst, & Damm, 2017).

Security and Privacy

Security and privacy issues are also an important part of CIS architecture (Taherkordi et al., 2018). For example, medical data of the particular players are collected and therefore require the highest security standards. Sports clubs, especially football clubs, are very critical about that topic. This can already affect basic architectural decisions, for example, whether the CIS must be hosted on external or internal servers. The rights governance for individual users is very detailed and must be able to be adapted independently and at short notice. Official regulation on data protection and privacy (e.g. GDPR (The European Parliament and the Council of the European Union, 2016)) must be taken into account and followed in the system architecture. However, there is no uniform solution, it depends on the particular country and the individual club structures. The execution then also depends strongly on the technology used. Therefore, this topic must be considered in the CIS concept to make fundamental architecture decisions, but then becomes more relevant in the subsequent phase of the PSM.

In this section, basic methods of software engineering were used to determine the requirements for a CIS. Based on this and considering models from business intelligence and sports science, an architectural concept was developed specially for sports clubs. In the next section, the typical problems with practical implementations of CIS in sports clubs will be outlined addressing specific problems of the setting, and strategic as well as organizational problems.

Practical experience on problems during development and deployment of CIS

One of the authors had the opportunity, in cooperation with clubs (three clubs of 1st Bundesliga) and as an employee of a club (2nd Bundesliga), to gain many years of experience in the development and implementation of information systems in sports. Within a participating observation, the observer was employed as embedded scientist half-time at the university and half-time at professional football clubs with frequent exchanges with the entire staff. This provided the opportunity to get an impression of the work processes of the club as a permanent part of the team and to document it. The following observations show some specific problems of developing the concept and the practical implementation of such CIS. These problems can be divided into a strategic and an organizational perspective. The purpose of this participating observation was not to present a quantitative description of the problems, but rather a qualitative summary of typical problems in the operational procedures of professional football clubs dealing with IT systems.

Specific problems in the context of sports clubs

A fundamental problem at football clubs is that the most relevant staff members are tied up in day-to-day business. Therefore, important staff members often do not devote much time and do not see any added value in getting involved in CIS development. Meetings are very difficult to organize because they are often planned at very short notice, e.g. when subordinated to the necessities of day-to-day training. In general, daily work is strongly influenced by match results. After a period of lost matches or the threat of relegation, the entire club is paralyzed and thinks only from day to day and strategic long-term decisions for the further development of the club are not made. In the case of sporting success, in contrast, even larger investments are decided spontaneously and without evaluation, but often without planning long-term integration of the new investments.

There is high fluctuation, especially among decisive staff members like head coaches. This makes long-term involvement difficult and following staff members then have different goals. As Figure 2 shows, the head coach takes a central position in the training system. However, despite their central importance, these positions are often changed short-term. In the time before the dismissal, usually not much happens anymore because the coaches only think from game to game. With the arrival of a new head coach, he/she has to become familiar with the club structures and acclimate to daily business. Because of his/her central position and great influence, the structures in the club can change fundamentally. Even long-term decisions are rejected if they are not supported by the leading management. This participation observation was aggravated by the fact that various employees in leading positions changed several times as a result of sporting development. Subsequently, structures were fundamentally changed and it took weeks until a first meeting for the presentation of the CIS was arranged. In two cases there was even another change of the head coach shortly after this first meeting.

Strategic Problems

A central finding is the general *underestimation of the demands* of the task of implementing a CIS. The task is hardly seen as strategic organization development, a project requiring persistent involvement and support by leading managers. For example, it is hardly considered in advance which questions of the specific users are to be answered with the help of the data. However, this is essential for data modeling to determine which data needs to be provided by the source systems and imported into the CIS to answer these questions.

Frequently, we see a strategic *communication problem*. With representatives of IT companies without practical sports experiences and sports practitioners without a necessary understanding of IT, two very different organizational cultures and methods meet, who often do not understand the other side. For example, it has become common practice for player load management to specify each training day in relation to the next match day (e.g. training one day before matchday = matchday-1). To monitor this information in CIS, it must be included in the export by the tracking system (= source system) to be imported into CIS. In this observation, it was not the case, and this interpretation was not available to the trainer or had to be laboriously solved by a workaround. However, this is not a technical problem, but a system requirement that must be defined in advance between the users in the club, and the CIS and tracking system provider. Such a task requires interdisciplinary communication, which could be solved by sports informatics expertise.

This leads to the problem of a *lack of integrating sports informatics*. This is also a consequence of the two problems above, as often the need is not seen by club managers and IT companies. This may result in a variety of consequential problems that can run through the entire planning, design, integration, and deployment process. This could be, for example, the specification of interfaces between source systems and CIS. There is no routine answer because the options of the source systems have to be coordinated with the demands of the CIS users, where a sports informatics background can be helpful.

As mentioned above, system requirements are often insufficiently determined. The systematic analysis of the organizational structure and the training system is, however, a decisive project phase. Neglecting this can lead to a lack of proper specification of the organizational requirements, which in turn form the necessary basis for defining the system requirements for a CIS.

The missing system and organizational requirements make product analysis and selection more difficult. Without these determined requirements, it is almost impossible to create an individual CIS concept for the club to check the offered software products detailed for their applicability and to use this as a basis for an independent and structured product decision.

Organizational Problems

Often prevailing management structures lead to isolated decisions without consulting the respective experts. The experiences show that many sports clubs are still managed in a very traditional manner and decisions are often made top-down by one or few individuals without involvement of the respective specialists. Rarely profound, independent, and structured product analysis forms the basis for product decisions, but rather personal contacts to or promising product presentations of companies. A consequence of this can be that employees do not accept this decision and do not support the introduction of the system. Experience has shown that this can lead to a delay in system integration and even result in the failure of the entire project (Charette, 2005).

Moreover, the organizational structure in the club is often not adapted to the new conditions with a CIS (Jayal et al., 2018). Such a system runs alongside instead of being actively integrated into the club and its processes. An expert with the necessary expertise and authority, supported by management, is often not employed. Someone, with a sports informatics background, who should be engaged before a decision is made to purchase a new CIS and who is clearly positioned in the club to supervise the project from the beginning. Instead, typically existing employees, without the appropriate knowledge, are delegated to do the task in addition to their existing work. This problem could be alleviated involving people with a background of sports informatics that could provide necessary knowledge for the development of a CIS tailored to the needs and existing structures of the club.

Another problem could be inadequate information management within the club. Such a CIS is often installed without clearly communicating responsibilities. All employees concerned should be forced to work with the CIS, to fulfill the preparatory tasks and to provide their existing data. In this case, the participating observer with a sports informatics background was installed. But this happened after the product decision and neither his activity nor the binding use of the CIS were clearly communicated in the club. Some staff members did not give insight into their specific data, did not share it, did not support the information needed, did not work with the new

CIS or did not fulfill the necessary tasks. This was due to their daily workload, concerns about loss of information or simply a lack of personal added value. Some staff used any missing features or different processes in the new system as an argument against the use of the new CIS.

In this participatory observation, the CIS was deployed very quickly, ready-to-use for the particular departments, and interfaces, where available, were set-up. But the integration into the club structure and the daily use of every department has been delayed considerably.

Resume

This paper provides a new approach to the design and architecture of information systems in sports clubs. It is driven by an interdisciplinary sports informatics perspective and independent of manufacturers. Existing technologies are brought together and methods of different areas relevant for CIS are worked out and integrated (objective 1). From software engineering, theoretical basics were determined and existing models were used. Since similar challenges are dealt with in business intelligence, best practice models (e.g. three-layer model) were transferred to the present case and adapted. With training systems and information systems in sports, sports science provides a theoretical background for the demands for such a system that has been integrated into this concept. Since sports practice is a special case for the development of a CIS the needs of sports clubs were systematically identified using appropriate methods from software engineering and integrated into the development of the concept. Based on a participating observation, interviews, and questionnaires, the organizational requirements of the club were derived, key requirements determined, which in turn formed the basis for the system requirements (objective 2). On this foundation and considering design models from BI, a corresponding CIS architecture was designed on a higher level of abstraction (objective 3).

This systematic concept highlights the complexity of this topic, which can hardly be solved from only one perspective (sports practice or IT companies). Rather, interdisciplinary sports informatics is needed here to build a bridge and also to include other relevant disciplines and fields that provide fundamentals within the context of sports. The participating observation within a sports club was decisive for the system analysis and the design of the concept and differs from other work. The methodological decision to collect relevant information about the actual needs and the peculiarities of the setting proved to be very successful. Looking at previous works, these are more general (Blobel, 2009; Blobel & Lames, 2016), they only cover subareas (Blobel & Lames, 2018; Rein & Memmert, 2016; Shah et al., 2015; Stensland et al., 2014), or they just worked with questionnaires and interviews from an external position and focus one specific software provider (Shah et al., 2015).

This work provides methods and models to identify and illustrate the needs in sports clubs for a CIS. The architectural concept developed here is a general approach. Thus, it is flexible enough to adapt it to the individual club characteristics. On the other hand, due to the higher abstraction level of the CIS concept, no architecture is presented that can simply be transferred like a detailed blueprint to a particular club. Moreover, the concept was meant to be independent of a specific manufacturer, thus allowing an informed decision on the choice of the CIS environment. This means also not giving recommendations for any specific software products, programming languages, frameworks or hardware components. Finally, the chosen level of abstraction implies that the architectural concept suggested is not limited to football clubs but can also be transferred to other sports or sports organizations like federations or sports supporting institutions.

The requirements for a CIS defined in this work, which are shown in Figure 4, are concurrent with the current trends for BI systems, as Gartner's (Howson, Richardson, Sallam, & Kronz, 2019) and BARC (Business Application Research Center (BARC), 2019) BI trend reports show, as well as two reports of the BI companies Qlik (QlikTech International AB, 2019) and Tableau (Tableau Software Inc., 2019). The keywords *cloud-based*, *process-driven*, *self-service*, *mobile*, *storytelling*, *machine learning*, and *contextual analysis*, correspond with the demands of a CIS. At the BI trend reports, two terms appear a little newer: *Natural language processing* (*NLP*) and *internet of things* (International Telecommunication Union (ITU), 2012) *analytics* (*IoT analytics*). NLP focusses on user interaction with technology, accessing data, and interpreting evaluations by using natural language. IoT analytics is about handling information generated by different devices and generate useful outcomes by analyzing this data. This is one of the currently most discussed IT trends in general (Business Application Research Center (BARC), 2019).

Both topics are also interesting for a CIS and have long been present in sports science. The human-machine interaction using natural language as part of multimedia systems in sports was described by Mehler as early as 1997 (Mehler, 1997). For years, sports science has been working with different sensors to make the performance of athletes measurable. The complexity involved in creating meaningful analyses instead of simply forwarding sensor data has already been outlined (Kornfeind, Baca, Heller, & Dabnichki, 2009). Even though the terms NLP and IoT analytics have not been used in these early works, both describe the challenges and ideas behind. This shows that the CIS concept developed in this work can not only benefit from other areas, such as BI, but sports science can also provide approaches in return.

As a first practical application, the CIS concept presented here could be used by sports clubs in cooperation with a CIS expert to identify and illustrate their internal structures and processes. Based on this, they can adjust the CIS concept to their club structures with the existing IT infrastructure to address software providers more precisely. Software companies can use this CIS concept to compare it with their existing software architecture, to adjust it or use it for new developments. It could also be interesting for federations facing the challenge of using an information system for the consistent collection and analysis of players' data from different home clubs. In the best-case scenario, it will be used by both the club and the IT company during a system introduction to have a common basis and thus to make the introduction phase of the new CIS as efficient as possible and to be able to exploit the full potential as quickly as possible.

A final outlook must mention the necessity of a follow-up study that compares existing software solutions of IT companies for CIS with the system characteristics of the suggested CIS concept using evaluation research methods based on a market analysis. Another worthwhile source of information for sports practice would be to describe the implementation of such a CIS with appropriate scientific methods based on detailed use cases. This would make it possible to present the individual requirements in more detail. Due to the complexity of such a CIS for an entire club, it would be useful to focus departments, such as the medical department or strength and conditioning. Thus, the complete process from data collection to the user interface could be represented. This would allow a much more detailed understanding of the source systems, file formats, workflow, and the required user-specific information and presentation. Sports clubs can benefit from numerous advantages of such information systems. This opens up great opportunities for the future to centralize large numbers of isolated data sources in one system and get better insights. However, it requires an interdisciplinary view and help of sports informatics. This is achieved, for example, by specialists, with the necessary authorization, who are integrated into club structures. The sports informatics approach chosen here proves to be a starting point and also shows the need for further work in this field. This work also shows that such a CIS should not only be evaluated from a technical perspective but also from an organizational point of view. Purchasing a CIS is only one first step. Rather, the entire process, from data collection to analysis, must be considered to adjust it to the individual needs of the club. This requires great experience and appropriate knowledge of experts from sports informatics in dealing with data and systems involved.

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