DIGITALIZATION AS ENABLER FOR A HOLISTIC CORPORATE PERFORMANCE MANAGEMENT

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ABSTRACT

A holistic approach to digitization enables decision-makers to achieve new efficiency in corporate performance management. The digitalization improves the quality, validity and speed of information retrieval and processing. At present, most corporations are confronted with the problem of not being able to organize, categorize and visualize decision-relevant information. To meet the challenges of information management, the Management Cockpit provides an information center for managers. In accordance with the specific working environment of the executives, the Management Cockpit offers a quick and comprehensive overview of the company's situation. Today, the current situation of a company is no longer only influenced by internal factors, but also by its public image. Social media monitoring and analysis is therefore a crucial component for the external factors of successful management. Real-time monitoring of the emotions and behaviors of consumers and customers thus contributes to effective controlling of all business areas. The intelligent factories promise to collect data for internal factors, but the current reality in manufacturing looks different. Production often consists of a large number of different machines, with varying degrees of digitization and limited sensor data availability. In order to close this gap, we developed a compact sensor board with network components, which allows a flexible design with different sensors for a wide variety of applications. The sensor data enable decision makers to adapt the supply chain based on their internal and external observations in the Management Cockpit. Due to the realtime- and long-term monitoring and analytic possibilities the Management Cockpit provides a multidimensional view of the company and supports an holistic Corporate Performance Management.

Keywords: Corporate Performance Management; Management Cockpit; Decision Making; Data mining

INTRODUCTION

In order to remain competitive in the long term, companies need to use different concepts to reduce costs and maximize the utilization of available resources. For this purpose, individual performance management tailored to the company is frequently used, in which different management concepts can be applied with separate instruments, tools, processes and systems. Problematic, is that the used instruments have not been planned strategically or systematically, instead they have grown historically from many individual decisions within the different departments. As a result, data and information from different systems with various technical and methodological backgrounds are collected and presented in the management reports. In order to be able to make strategic decisions on the basis of this data, the reports must be carefully evaluated by questionnaires and clarifications in an attempt to achieve the necessary transparency. Accordingly, the investigation of these reports

may lead to further delays in the decision-making process. Furthermore, due to the inaccuracy or transparency, critical decisions can be made on the basis of a lack of interpretation or critical circumstances discovered at a late stage. To counteract these consequences, there must be increased transparency in the processes and process flows and thus a more efficient use of operational resources. Corporate Performance Management (CPM) is a defined generic term that describes all methods, processes, systems and metrices that can be used to monitor, measure and control the business development of a company (Geishecker, 2002). CPM thus describes various implementations of management processes and business methods that systematically improve the strategy of organizations. For optimum benefit, CPM must take a holistic view of the company and all other data that have an impact on the organization. Especially in the age of digitization, decision-relevant information can be procured digitally in order to be processed, analyzed and distributed faster.

KEY TERMS AND DEFINITIONS

In order to fully exploit all possibilities, companies must be able to handle the ongoing process of change that the digital age brings with it. In particular, the procurement and processing of information with the help of digital technologies or applications should be focused within the scope of corporate management to be able to make full use of exploitation potential.

Digital Transformation

The term "digital transformation" was already introduced at the end of the 1990s and has today again initiated a new trend for increasing digitization in the economy (BMWi. 2017). Digitalization improves the quality, validity and speed of information acquisition and processing. By considering the aspect of digitization in CPM, a holistic approach to digitization specifically enables a new efficiency for the decision makers. This promises to drive new innovations, increase efficiency and improve services (BMWi. 2017). Nevertheless, in addition to many advantages, problems arise such as the organization, categorization and visualization of decision-relevant information, which many companies cannot cope with due to the high amount of data. In addition to the pure consideration of data problems, the handling of new opportunities arising from every technological change requires the corresponding competencies of the employees in order to fully exploit the potential of a company. The technology must be added to the tasks of the highly and low-skilled workers, which can lead to a shift in the required qualifications (Acemoglu, Autor, 2011). This results in a complementarity between technology and qualification, in which a direct dependency exists on both sides. Thus, the individual and organizational competencies can be regarded as a resource that provides competitive and productivity advantages in addition to the technological state of a company.

Information systems for management

Qualitative information can improve the decision-making of managers or executives in companies. This is the reason, why they regularly look for as much information as possible to fulfill their various management tasks (Lueg, 2001). A variety of different information resources such as print media and online data sources are used for this purpose. The information provides different perspectives on customers, competitors, market development and legislation from the internal and

external environment (Shahriza Abdul Karim, 2004).To meet the challenges of information management, the Management Cockpit offers an information centre for managers. According to the specific work environment of the managers, the Management Cockpit offers the possibility to get a quick and comprehensive overview of the situation of the company. Real-time monitoring of consumer and customer behavior contributes to effective controlling in all business areas.

Enterprise Social Media & Social Media

By networking within an Enterprise Social Media (ESM) each employee is able to achieve an additional increase in his personal qualifications by exchanging knowledge with other participants (Kane, 2015). The knowledge exchange is facilitated by an interactive environment that allows employees to send direct messages, texts and files to specific employees or post them to the organization via web-based platforms (Leonardi et al., 2013). Another added value for companies using ESM is the new self-marketing and relationship building opportunities that can have a direct impact on the socialization of new employees and through active participation can lead to a stronger sense of community and commitment. For the assessment of the current situation of a company, however, it is not sufficient to consider the internal factors alone, but the image in the public must be taken into account. Real-time image measurement can be derived from social media data. Using social media data generated analysis, companies can better understand why customers buy a product or service and play an important role in securing competitive advantage (Brooks et al., 2014). Thus, social media monitoring and analysis is a decisive component as an external factor of successful management.

Cyber Physical Systems

The current management systems for production planning and execution are mainly based on static manufacturing information where decision-making processes are iterative (ElMaraghy, Nassehi, 2014).

The factors of production execution, such as changes in orders or priorities, environmental conditions and unexpected internal and external events are not taken into account. The consequences are unexpected interruptions, short-term repairs and long overdue maintenance during production operations with a waste of time, energy and resources (Wang et al., 2015). One solution for these problems is the Cyber Physical Systems (CPS), in which specific networked sensors provide their data in real time for evaluations for condition monitoring and diagnosis (Monostori et al., 2016). The use of sensors on machines does not yet represent an innovation or added value for the operating companies. Only when network components are used to network and transmit the data to the systems does this allow users a new data basis that can be used for decisions. It is important not to focus on individual production plants, rather to take a holistic view of all production resources that are directly or indirectly dependent on each other. It is therefore particularly important that data from all related production plants can be collected, condensed and analyzed. Unfortunately, the reality today in the manufacturing sector is very different. On average, less than a quarter of machines in Germany are connected to the Internet (Tropf, Zehl, 2018). Although the number of suppliers equipping their machines with additional sensors for monitoring and analysis is growing. These are usually only intended for the manufacturer himself and can usually not be viewed by the customer at all or only via proprietary software that does not permit further data transmission.

Internet of Things

The Internet of Things (IoT) describes the structure and interaction between sensors and actuators of physical objects connected to the Internet via wired or wireless communication (Atzori, Iera, Morabito, 2010). The use of IoT in production has encouraged the government of Germany to refer to the new possibilities as a new industrial revolution called Industry 4.0 and to initiate it (Shrouf, Ordieres, Miragliotta, 2014). In these IoT-based Smart Factories, production plants can be directly or indirectly equipped with sensors and provide their measured values via the network. This enables real-time recording and analysis of decision-relevant data of internal factors. However, the problem of the participation of different production plants in a production process with a different degree of digitization still remains. This results from the purchase of production machines, which involve high investment costs and are therefore designed for a long service life.

DESIGNING A HOLISTIC CPM

With a holistic CPM it is possible to integrate information into the operational process flows and to use corporate resources efficiently with regard to their use. The data can be collected, analyzed and checked for interconnection both internally and externally. As a result, CPM allows a company's methods, systems and processes to be viewed holistically and an optimal decision made on the basis of the underlying information. This is made possible by the conditions in the Management Cockpit, which allows the analysis and combination of a wide variety of data at a glance. On the one hand, this identifies possible correlations and on the other hand, new future states are simulated and visualized.

Figure 1. Layer-based architecture model for a holistic CPM

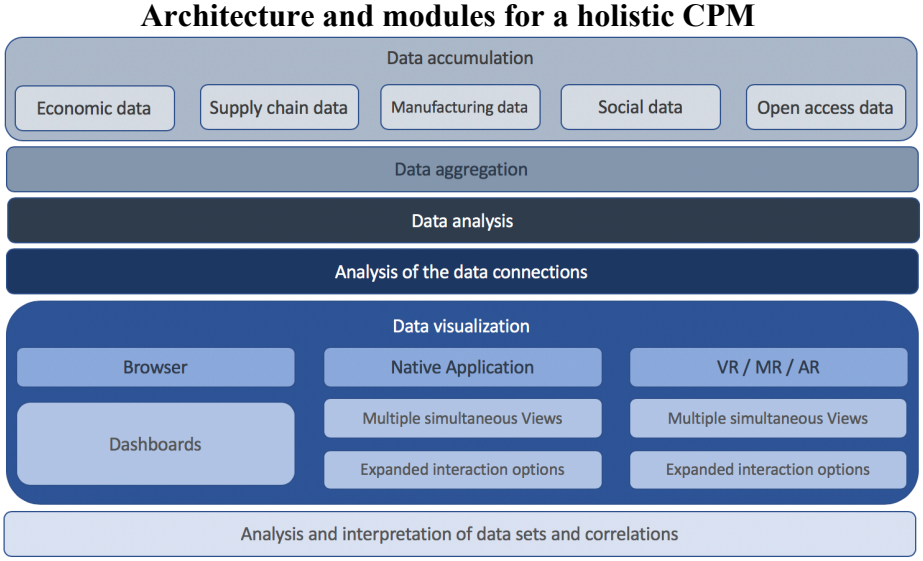


Figure 1 shows the architecture of holistic CPM. It describes the structure from data acquisition within the first layer to iterative data analysis and data visualization in the last layer. The individual layers will be discussed in the following subchapters.

Data accumulation

The Economic data describe all business data that can be read out of the own obtained operative information systems. A similar situation applies to the supply chain data. These also represent operational data that can be read directly from the information systems for the supply chain management (SCM). Manufacturing data are data sets that are provided by manufacturers to individual facilities in real time. By using IoT, machine data or data can be generated between the individual production steps and would therefore be a possible solution, since many manufacturers do not allow data access as already explained. The module Social Data describes the data that can be obtained from social media and enterprise social media. It should be taken into account that many perspectives on the company are considered, as well as Open Access Data allows.
Open Access Data describes all publicly accessible data that have a direct or indirect influence on a company's own performance. The data sources are dependent on the area of business field in which the company operates. As a result, competitive advantages can be secured and the competition identified early on, as important information regarding new products, developments, pricing, current topics or the presence of new market participants can be collected from public sources, such as a company's website. Different options can be used to collect and provide the data. Initially, the data can be procured and exchanged between interconnected actors via common software. The data can be displayed within the own software or made available via defined interfaces, also called APIs. Another alternative are self-developed web crawlers for individual websites. This allows to collect any number of information from a website and its links to be automatically called up, monitored and extracted to data sets.

Data aggregation

After the data has been retrieved, it must be stored persistently in databases. When selecting the database, the scope, the level of detail and the period must be taken into account. This allows to use the current and historical data for analysis and to show the changes based on data that serve as an additional source of information. To obtain a top down view for the management it is evident to aggregate the data in several views.

Data analysis

The data analysis describes the sole consideration of the data sets from the individual sources. The known business analysis methods can be used for the operational data. To this end, certain key performance indicators (KPIs) must first be defined and clearly specified. This is achieved through the creation of key figure profiles. These summarize the most important information on the individual KPIs. A further data analysis is defined under the heading "Social Media Monitoring", which means the continuous collection, the resulting evaluation and the presentation of user-generated content from various social media platforms. As a result, companies can observe which conversations are held by consumers about their own brand, products or even current topics. Particularly in data analysis, companies have the possibility to choose between different types of monitoring. In the case of strictly technical monitoring, the use of Social Media Monitoring Tools is limited, since an intellectual evaluation for the knowledge determination is completely abstained from. Possible applications are customer care, support, competitive observation, trend analyses or market analyses. These can have a high influence on the reputation management as well as on the

image of the companies. Especially social media monitoring tools are used in this area to allow continuous observation. In the case of manual monitoring only, social media monitoring tools are not supported. In this process, user-generated information is searched for and evaluated manually, for example via a search engine. However, the problem is that due to the high amount of information, only a small fragment of the potentially important information can be accessed. For this reason, many companies use manual monitoring in addition to strictly technical monitoring to collect random sample analyses such as consumer opinions. In addition to the analysis of raw data from social media and enterprise social media, the data can also be used for a deeper analysis via text-mining applications to complement the sentiment analysis. The analysis of the data should then help to support management decisions, while taking the corporate strategy into account, and thus to manage the company successfully.

Analysis of the data connections

This module contains various applications and algorithms that can be automatically applied to the collected data sets. In contrast to the previous section, the focus of this module is not solely on viewing data sets from individual sources and their individual values, instead it focuses on recognizing predictions that only arise from viewing the relationships between data sets from different sources. For this task, machine learning can be used to identify automatically the potential connections, or algorithms that have been developed based on human understanding to recognize complex relationships. The ability to detect important correlations from different data is taken over by decision makers in the last section "Analysis and interpretation of data sets and correlations". If correlations have been found which can be processed by algorithms, this task is applied to the data sets in this section.

Data visualization

There are various options available for visualizing the data, but they all access the same data basis. Therefore, the question of the best type of visualization is not of fundamental importance, as each brings advantages and disadvantages and a combination should always be in the focus. In the browser, the information is visualized using dashboards, as the information can be divided thematically into individual dashboards. This type of visualization can be used in many ways, as only internet access is needed. Often small display areas are disadvantageous, because you have to change through many dashboards to get a holistic overview. Using a native application, a large number of display areas can be viewed at the same time. Navigation can be used for all display areas. In this way, individual displays can be changed at the simultaneously, but also over a large number of displays, if this corresponds to the context. If the social media data have been edited accordingly, however, they must be visualized in a management-oriented way for later analyses. Only in this way is it possible for the management to determine the corresponding corporate strategies. The Management Cockpit at Reutlingen University offers the ideal platform for this. Complex data can be visualized clearly for the management via a large number of monitors and beamers. Features such as touch-screen navigation and control by gesture allow data analysis and thus decision-making for all members of a meeting to become more interactive and clearly illustrated.

Analysis and interpretation of data sets and correlations

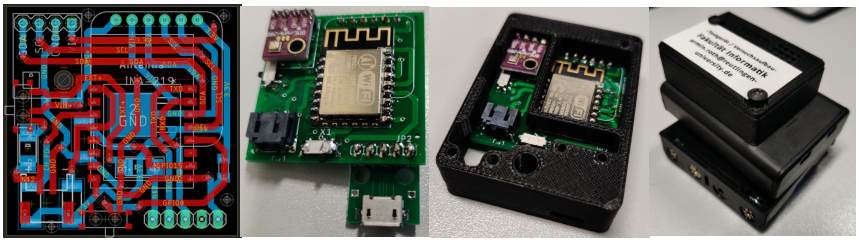
In this section, the decision-makers interpret the collected and processed data by use of the visualization section. As described at the beginning, it is not sufficient to consider individual data alone. For a holistic view it is necessary to identify and analyze the connections between the different data sets as well. Advantageous is a large variety of simultaneous views on the observable data sets and groups, so that correlations and patterns between the data, which are not recognizable by focusing on individual data groupings, can be identified. Thereby advantageous is a large variety of simultaneous views on the visible data sets and groups, as it is offered by the Management Cockpit (Roth, 2015), so that correlations which would not be recognizable on the view of individual groupings can be identified. The connections are transformed into algorithms and are integrated into the section "Analysis of the data connections" and form a permanent part of the data processing.

IMPLEMENTATION

To give a concrete picture of the methodology presented for comprehensive CPM, we describe in this section an implementation according to the model presented in the previous chapter for measuring manufacturing equipment, working environments and competitive analysis, which are used in addition to the data from the internal information systems. Since a competitive analysis can be carried out at different levels, a market definition by product, territory and customer segment is used.

In designing a sensor box for real-time data analysis of environments and manufacturing facilities, care has been taken to ensure simple usage without a deeper understanding of electrical engineering, so that the focus of users remains on data collection and analysis. As micro-controller, the ESP8266 was used, because it already has a built-in Wireless Local Area Network (WLAN). For the various applications, the developed code includes the modules BME280 (temperature, air pressure and humidity measurement), MMA8451 (acceleration sensor) and TSL2591 (brightness sensor), which can be connected to the PCB via the Inter-Integrated Circuit (I^2C) bus and can be activated or deactivated in the software, depending on the configuration, in order to cover the sensors that are often required. When using the developed sensor board, it is thus possible to set up the required configuration quickly for a production plant or a specific environment without having to carry out specific software development on the micro-controller. Further sensors can also be connected and integrated into the existing structure by further code development. The developed sensor board has a 2-sided PCB layout, is 2.5cm x 2.5cm in size and is installed in a 3-part 3d-printed housing. The modular housing design was used in order to make only individual part modifications according to the assembled sensor box configuration with an internal or external power supply. The finished sensor box is shown in the following figure.

Figure 2. Sensor box with schematic representation of the PCB, the manufactured board and in the assembled condition in the configuration with the BME280 sensor and 2 battery packs.



For the asynchronous acquisition of the sensor values the Message Queuing Telemetry Transport (MQTT) protocol with Mosquitto as broker was used. For message exchange, the broker provides queues that are subscribed by clients and thus receive new messages when they are sent to the queues. For the logic mapping, Node-RED was chosen to network the hardware devices and Application Programming Interfaces (API), since plug-ins allow the integration possibilities and functionalities to be expanded quickly. A Transport Layer Security (TLS) encryption with certificate was used for the encryption of the connection between the hardware for sensors and the broker, with an authentication of the server as well as the encryption of the sent messages from the sensor boxes.

Relevant data from various sources were extracted for the competitive analysis. This data was collected from social media channels using APIs and Open Access data. The Open Access data represent publicly accessible data that is freely accessible via the Internet and can therefore also be captured automatically. For this purpose, information and documents from the websites were automated extracted using a developed web crawler and then archived. The Scrapy framework was used to extract the data from the web pages and the Camelot and tabula-py libraries were chosen to extract the data from the linked PDF-documents. The following three components with the associated questions were focused in the competitive analysis:

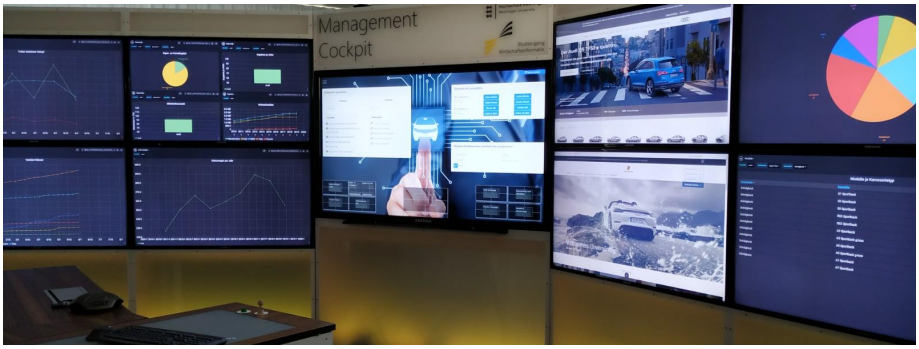
- KPI's of the companies - How are the companies generally positioned (e.g. how high are the sales figures, how high is the profit?)
- Product information - Which product strategy is used and which technologies do companies currently rely on?
- Market information - How are the companies positioned in a certain market (e.g. how high are the sales figures and how active are the companies in the social media?)

For the data archiving of the sensor values and the analyzed data the object-relational database system PostgreSQL was used and for the raw data archiving of the social media the NoSql database system MongoDB was employed. Analyses were made from the stored raw data using data mining and sentiment analysis.

During the development of the visualizations, the representation as web pages was chosen, since these offer a high reusability and adaptability. Thus the individual web pages can be used as reports and at the same time also for native applications with extended navigation functionality, in which the individual reports can be displayed distributed on monitors and provide information about the key figures at a glance. Reutlingen University's Management Cockpit (MC) with its large number

of monitors offers optimal conditions for the presentation and evaluation of data. It has a large main screen with touch function as a central control environment and eight additional monitors for data visualization. The framework Electron, which is based on Chromium and Node.js, was chosen for embedding the web pages in a native application for the MC. With the help of these web technologies an execution on all browser compatible operating systems is possible. During the development for the MC it was considered that there is an additional control possibility so that data is always displayed for all views (one view describes in this context the individual view on a monitor) in the same period. In our implementation we have therefore designed the interaction with the web pages in such a way that they can all be called parameterized. As a result, competitors or sensor values and the comparison period for all open views can be defined together via the central control option. Further filtering and adjustment of the displayed data can still be carried out in the individual views. In order to keep the thematic constellations (i.e. the view of all active views in the MC) directly accessible, e.g. to be able to reopen the constellation with the latest data created for periodical meetings on a topic, a memory and call functionality for the constellations and the views was implemented. The last step involves the visualization of the information using middleware and the creation of a user interface to enable user-friendly navigation. The information is first displayed at a high level of abstraction and can then be analyzed in more detail with the typical OLAP (online analytical processing)- functions. This makes it possible to display diagrams in a simple and pre-structured way and to adapt them to requirements. A locally hosted version of the Grafana platform was chosen to display diagrams and graphics. Grafana can be used to query the databases. The results are then automatically converted into graphics. These graphics were displayed as native applications using Electron. The library D3JS was used for the graphic design of additional visualizations that could not be directly mapped from the database queries.

Figure 3. Developed competitive analysis application in the Management Cockpit



RESULTS

In the implementation we could show how a combination of soft- and hardware according to the presented model can be designed to enable a holistic CPM. By using Open Access data for competitive analysis, changes can be detected early on among competitors and used for the company's own goals. In addition to the use of real-time data, it also became apparent that the storage of competitors' historical data can also be an important basis for decision-making. Likewise, developments of new competitors with a low market volume and high growth rate can be discovered early and the trend development can be used for one's own company goals. In the case of the linking of production plants with a low degree of digitization, a possibility was shown, how these

facilities can be integrated in the context of industry 4.0 together with the new production machines for the measurement of internal factors. In addition to measuring the degree of utilization, operating characteristics and wear and tear of production equipment, the described setup also enables recording of different environments, such as the production or working environment. Recording the data from the environments enables a more comprehensive prediction of the company's performance. The flexible design of the sensor box for different purposes allows it to be integrated into the company's software. With the developed sensor box and the attached architecture an environment for advancements was provided. A comprehensive real-time view of the company's internal status can be displayed and analyzed. This joint view on data relevant to the company (internal and external factors), as described above, represents a broad view of the data collected in the past and in real time on the overall position of the company in terms of holistic corporate performance management. When designing the architecture for data acquisition and analysis, we outsourced this to our own modules so that data can be visualized in different forms, such as classic reporting or a comprehensive overview with interaction options in the MC. The comprehensive representation allows the identification of potential relationships and correlations between data from different sources, which can then be used for decisions and transferred to reports.

CONCLUSION

In the age of digitization there is an extreme potential to collect all for the company relevant data in an automatically way. After that we need efficient and reliable procedures and algorithms to gain decision relevant information and business knowledge out of this data.

For an holistic performance management it is necessary to cover all management perspectives:
- first perspective: management of legal entities and business units,
- second perspective: management of processes,
- third perspective: management of projects,
- fourth perspective: management of employees

and combine them in an integral management system (Roth, 2014).

The described architecture allows to collect and analyze the relevant data and prepare it for a comprehensive view for the management.

The Management Cockpit is able to visualize this complexity and to give the management the transparency over the progress in the strategy implementation, the success of the operations and the development of the company, the competitors and the trends in the market. With this prerequisites the management gains a real-time, overall view over the company’s situation and is enabled for a successful holistic corporate performance management.

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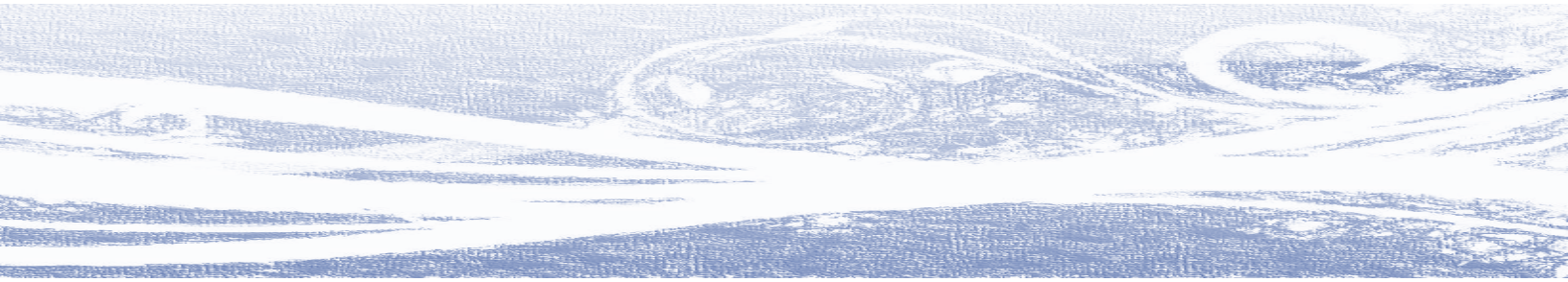

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