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AN ECOSYSTEM PERSPECTIVE ON ASSET MANAGEMENT INFORMATION

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Abstract:
Big Data and Internet of Things will increase the amount of data on asset management exceedingly. Data sharing with an increased number of partners in the area of asset management is important when developing business opportunities and new ecosystems. An asset management ecosystem is a complex set of relationships between parties taking part in asset management actions. In this paper, the current barriers and benefits of data sharing are identified based on the results of an interview study. The main benefits are transparency, access to data and reuse of data. New services can be created by taking advantage of data sharing. The main barriers to sharing data are an unclear view of the data sharing process and difficulties to recognize the benefits of data sharing. For overcoming the barriers in data sharing, this paper applies the ecosystem perspective on asset management information. The approach is explained by using the Swedish railway industry as an example.

Key words*: open data, data sharing, information management, information model, business ecosystem, asset as a service*

INTRODUCTION

Open data sources, for instance in the form of Big Data (BD) and the Internet of Things (IoT) have changed the business models in several ways. The increased number of partners involved in value creation, and access to a large amount of data allows for more complex business models and collaboration patterns. Rong et al. [1] claim that IoT is more than a support for the supply network; IoT should be understood as a business ecosystem. They also note that there is very limited research in IoT ecosystems. Thus, there is a need to understand the new business patterns and map the information requirements within business ecosystems. One attempt to model the influences of big data on different actors in the business ecology dynamically is found in [2]. Asset Management (AM) is a domain in which BD and IoT bring great opportunities, but also great challenges, for instance as regards the sharing of data. Open data can create new value by intensive and creative use of data, for instance resulting in the optimization of maintenance and operations, and prolonged asset lifetime. The service provider can for example give support for decision making by collecting data from several plants and identifying similarities in the data, and create new and better analysis based on the combined data.

One of the challenges is that a lot of open data appears in situations and activities that are different in context and time of its definitive use. When data is taken out of context, it loses its meaning. Operational data is usually defined at the point of creation in just enough detail to support the people who operate the system or use the data directly. According to [3], data collection, management, access, and dissemination practices have a strong effect on the extent to which datasets are valid, sufficient, or appropriate for further use. Data quality is generally understood in terms of accuracy, but studies have identified multiple aspects of information; quality is more than just accuracy of the data [4]. In [5] data quality is described as data fit for use by data consumers, including dimensions of accuracy, consistency and security, as well as relevancy and understandability.

Applying the ecosystem perspective in asset management is a way to overcome some of the challenges in information sharing. The purpose of this paper is to address the barriers for data sharing within AM by suggesting an ecosystem solution. First, an understanding of the barriers and opportunities for data sharing is created by using an empirical approach. Thereafter, a conceptual solution is suggested with support from contemporary ecosystems research. The paper is organized as follows: in the next section the relevant background regarding asset management is given. Next, the concept of data and information sharing is introduced, and the results of an empirical study of opportunities and barriers for information sharing within AM are presented. Thereafter, the ecosystem approach is utilized for conceptual modeling of a solution to the barriers for information sharing in AM. Finally, concluding remarks are given.

ASSET MANAGEMENT AND ITS INFORMATION NEEDS

Assets are entities that bring potential or actual value to an organization [6]. The value varies with the context, organization and situation, and could be tangible or intangible, as well as financial or non-financial. Asset management can be described as a set of activities for reaching a given business or organizational objective [7], including identifying the required assets and funding, acquiring the assets, providing logistics and maintenance support, and disposing or renewing the assets.

An organization defines the internal and external communications relevant with respect to the assets, asset management and asset management system: what, when, to whom, and how to communicate [8]. An asset management information system is designed to create and maintain documentation of asset management functions [7]. Asset management information systems are used to identity equipment, locations and activities. These systems are also known as Computerized Maintenance Management Systems (CMMS). Figure 1 shows the main applications of asset management information systems, which correspond with the information requirements for an asset [9].

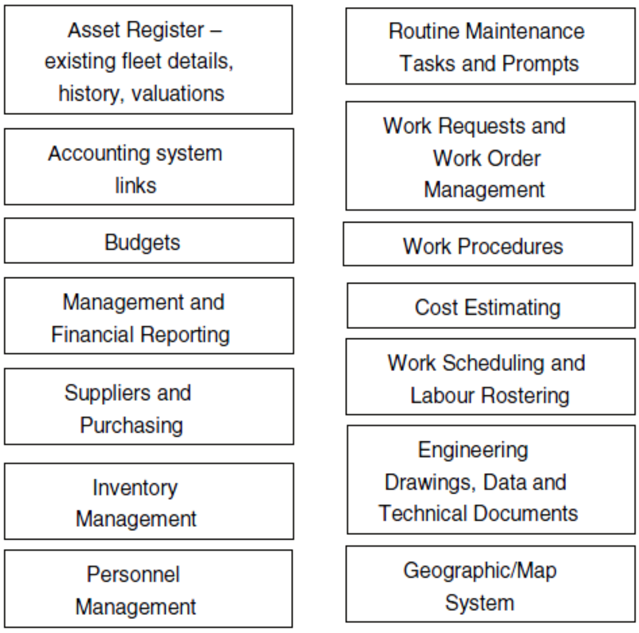

Fig. 1 Asset management information system
Source: [7].

The data requirements are different between fixed and mobile equipment. The main difference is location. In mobile equipment, Global Positioning Systems (GPS) and maps are probably needed [7]. The organization has to take into consideration the risks, roles and responsibilities, as well as the processes, procedures and activities in asset management, information exchange, and the quality and availability of information in the decision making processes [8]. Information in asset management activities is listed under the relevant subject areas: data management, condition monitoring, risk management, quality management, environmental management, etc. [10]. The organization determines the attribute requirements and the quality requirements of information, and how and when the information is to be collected, analyzed and evaluated [8].

OPEN DATA ACCESS

Open Data was originally a concept in which governmental data were available to anyone with a possibility of redistribution in any form without any copyright restrictions [11]. Nowadays the definition of Open Data is wider: “Open data is data that can be freely used, shared and built -on by anyone, anywhere, for any purpose" [28]. A clear and consistent understanding of what Open Data means is important if the benefits of openness are to be realized, and to avoid the risks of compatibility between projects [12]. All Open Data is publicly available, but not all publicly available data is open. Open Data does not mean that an organization releases all of its data to the public. Open Data means that data is released in a specific way to allow the public to access it. The focus is on what data is available and how the data is available. If Open Data is misread as releasing all data, privacy becomes an issue [13].

Data sharing has been recognized as a good behavior in science and technology research. Data sharing enables researchers to ask new questions based on shared data, as well as advance research and innovation [14, 15]. The medical community has found the benefits of data sharing [16, 17], such as the system of open access that was released to the pharmaceutical industry by GlaxoSmithKline in May 2013. The system contains patient-level data from clinical trials of approved drugs and failed investigational compounds. An independent panel decided which data was available to responsible users. Jansen et al. [18] classify the benefits of open data into political and social, economic, and operational and technical benefits. Political and social benefits include for example transparency, more participation, creation of trust, access to data, new services, and stimulation of knowledge development. Economic benefits are economic growth, stimulation of competitiveness, new innovations, improvement of processes/products/services, new products and services, availability of information, and creation of adding value to the economy. Examples of operational and technical benefits are reuse of data, creation of new data by combining data, validation of data, sustainability of data, and access to external problem-solving capacity.

In [18] the barriers to Open Data are identified as follows:

- institutional level barriers,
- task complexity of handling the data,
- the use of open data and participation in the open data process,
- legislation,
- information quality, and
- technical level barriers.

Institutional barriers are: unclear values (transparency vs. privacy), no policy for publicizing data, no resources, and no process for dealing with user input. Task complexity includes lack of understanding the potential of data, no access to original data, no explanation of the meaning of data, information quality, duplication of data, no index on data, the data format and dataset being complex, and no tools available to support. Barriers for the use of open data and participation are: no time, fees for the data, registration to download data, unexpected costs, and lack of knowledge to handle data. Legislation barriers are: privacy, security, licenses and limitations to use data, and agreements. Information problems are: lack of information, lack of accuracy of information, incomplete information, non-valid data, unclear value, too much information, missing information, and similar data stored in different systems yields different results. Technical barriers are: the data is not in well-defined format, absence of standards, no support, poor architecture of data, no standard software, fragmentation, and no systems to publicizing data.

Other ways to group the barriers also exist. For instance Saygo and Pardo [19] define the barriers from four perspectives:

– technological barriers,
– social, organizational, and economical barriers,
– legal and policy barriers,
– local context and specificity.

EMPIRICAL STUDY ON PRACTITIONERS' VIEW

In this section, the results of an empirical study of the barriers and benefits of shared information for asset management are presented. The study included seven interviews in total. The interview data was collected from managers and directors of four different departments at a Finnish Original Equipment Manufacturer (OEM), and from managers and directors of companies who purchase those products. Theme interviews were used, and the answers were coded with NVivo. The interviews and coding took place in Finnish, and the main findings were translated into English. The findings were classified according to the barriers and benefits to open data presented in [18]. The barriers were classified to the institutional level, the task complexity of handling the data, the use of open data and participation in the open data process, legislation, information quality, and technical level barriers. The benefits were classified to political and social, economic, and operational and technical benefits.

Barriers for data sharing

1. The institutional level barriers

The ownership of data is important. The customer owns data and wants to own it in the future: "Our equipment, our data". For example, customers do not want to reveal the location of equipment and health data. Data containing the customer's identification are not allowed to be shared. The same goes for production quality data and product recipe data. Other data can be shared if the advantages of sharing are clear. There is a prejudice against cloud computing in companies. A lot of data is available, but companies do not want to give the role of the data manager to anyone else, even though support is needed to analyze big data. The customer does not share data because they think that the supplier wants to take the maintenance to its own business. The demand for the monopoly of data is a challenge. The maintenance playground is fragmented and it has hundreds of doers, who have their own systems which do not work together. It is impossible to define a common platform, and there is no evidence that a common platform would appear. For data-driven maintenance, predictability and pricing models are challenges. The cost should be minimized, but remote control costs a lot. It is a challenge to sell data-based service because the customers are used to getting also maintenance staff at the same time.

2. Task complexity in handling the data barriers

The complexity in data management is growing, and it is difficult to notice important data automatically in a very large amount of collected data. Different data in different databases are seen as a challenge or as a barrier. In the future, the target is to use data better than today. The amount of process data is big, and it can be used for something else than just process control. Defining the monitoring of data is difficult. Process data is not collected by equipment, but health data is collected and used. There is no link between maintenance databases and automation systems.

Putting data into a database should happen only once, and the data should also be pre-selected in order to minimize mistakes. It is a problem that there is no data available of maintenance actions made in the past and about the condition of the equipment now. It is not known what data it is possible to collect from new relays. The data when the relay needs maintenance and the fault history are needed. The customer's needs are important, but not all wishes can be fulfilled. Technical skills and own knowledge can limit the offering of new services to the customer.

3. Barriers for the use of open data and participation in open-data process

The barriers to sharing data are lack of knowledge and insufficient grounds of value added for sharing data. The win-win situation is not understood. Many doers are afraid that someone else will have better understanding, and this prevents the sharing of data. Online data is not available but it can be organized in an emergency. Online data would offer other information, but customers do not have online data systems. Big data is not shared between divisions, although the advantages of sharing data are obvious. Now data is shared and combined only case by case when needed. With strategic partners, data could be shared more to do better analysis. Data is shared with the maintenance staff but not with the customer, and also combinations of data from different data sources are not used properly.

4. Legislation barriers

There are barriers for changing the processes (e.g. in the oil industry) because regulations specify the periods between maintenance operations. That is why it is not realistic to implement health monitoring. The regulations and laws are unclear. Regulations in the marine are local. Global emission measurement are not used as widely as local e.g. in the Baltic Sea. One could therefore ask whether continuous emission measurements are needed or not in maritime industry. Regulations will be tighter and more accurate than now in the future, and that will set up new demands for data collection and the presentation of data. When a supplier has a more eco-friendly solutions than others, then from their point of view tighter regulations is not a bad thing.

5. Information quality barriers

There is enough data, but the problem is that the data from Enterprise Resource Planning (ERP) is not accurate enough. There can be errors in feeding information to the computer and exploiting of it can be difficult. The biggest problem is the quality of the data from ERP systems because people can make mistakes when inputting data. The data is formatted "badly", it is on paper, or somehow else difficult to automate. Manual data is difficult to use.

6. Technical level barriers

Technology is available to collect big data, but standards are missing. It is difficult to define which data to collect. Integrated systems record data but not enough. It is impossible to see trends from insufficient data. The amount of data can be very big. Only Key Performance Indicator (KPI) data is analyzed and the whole data is checked if needed when problems are noticed. Integration is a challenge: how can all the needed data be collected through one cable and then used?

Benefits of information sharing

1. Political and social benefits

In the future, open data can be described as a "sharing economy" which affects positively between companies and service networks. Transparency in data sharing enables new business models. New ecosystems are spoken of, but when creating a new ecosystem a lot of dialog with different parties is needed. More responsibility is needed from both supplier and customer when implementing new models. If "risk and revenue sharing" is the target, also the supplier needs to give more and take more risk and responsibility in order to get the client come in.

2. Economic benefits

There is need to consider the value of the service for the customer. Different data from the divisions can be combined and new services can be offered. The potential of big data is interesting, as well as knowing the risks. The service plan is based on existing technology and know-how. The business view is essential when developing new service products, and production is more important than one client's needs. Training is needed when business is transferred to data-based services.

3. Operational and technical benefits

With more automation decision support proposals can be created to maintenance staff. The equipment could create data for the maintenance staff automatically, e.g. work orders. The clients want both support for decision making and data analysis to be used in decision making. Data is collected, and support to optimize energy consumption is given. Also remote support, fault diagnosis, health monitoring are possible because the equipment is "intelligent". The supplier cannot lock itself to the business model used. Some clients want to try new models and some want to change action only when forced. The ability to offer services for different environments is needed. Data analysis and decision support are needed, as well as traffic lights to observations of data.

4. Potentials for data sharing

The more aware the client is, the more data they will demand. Data user rights need to be defined. Online data is not yet in use, but with measurements, the data can help to recognize the need for maintenance, as well as point out the benefits of maintenance services. The amount of big data is huge, but it is used at quite a low level. The target is to prevent failure situations by managing big data. Data can be transferred from clients also with remote control to create new services for them.

The client company collects data and understands what is needed. The supplier should pay attention to data analysis and give support to the clients in their decision making. Is the data analysis done in order to develop the supplier's own business and processes or to create added value to customers? Usually companies have strategic-level support decision tools, but they expect the service providers to offer tools for operational-level decision support. Service contracts are based on condition monitoring of equipment and in the next step on data, and then right services are available at the right time. E.g. history data is now only used in troubleshooting but there is potential for forecasting the need of maintenance and using databases better, as well as using life-cycle data. Developing processes and automation systems can be seen as a possibility to develop data management. Now data is collected time-based online. It is easy to share data which is collected by equipment, also analysis and reports to the customer are quite normal actions.

BUSINESS ECOSYSTEMS

Introduction to ecosystems

The traditional view of value creation is in the form of a stream, or a chain, where the actors interact by refining input e.g. in the form of raw material to output in the form of a finished product. The value chain could also describe service creation, such as the Swedish railway industry value chain depicted in Figure 2.

In reality, the situation is often more complex than that, as outsourcing and n-party collaborations also connect players to each other in star-like or network patterns [21]. Moore has introduced the concept of business ecosystems as a way to describe the changed business environments characterized by uncertainty and co-evolution [1, 22]. According to [22], a business ecosystem is an economic community consisting of interacting organizations and individuals, which are the organisms of the business world. The ecosystems create value for the customers in the form of goods and services. The traditional actors in a value chain (customers, producers and suppliers) are included in the ecosystem, but also other stakeholders are recognized as actors, such as competitors and public authorities [20].

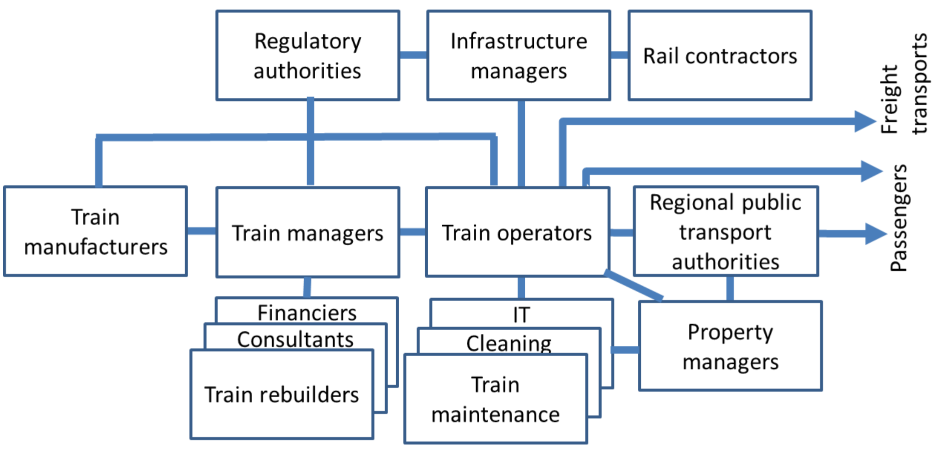

Fig. 2 The value chain of the Swedish railway industry
Source: [20].

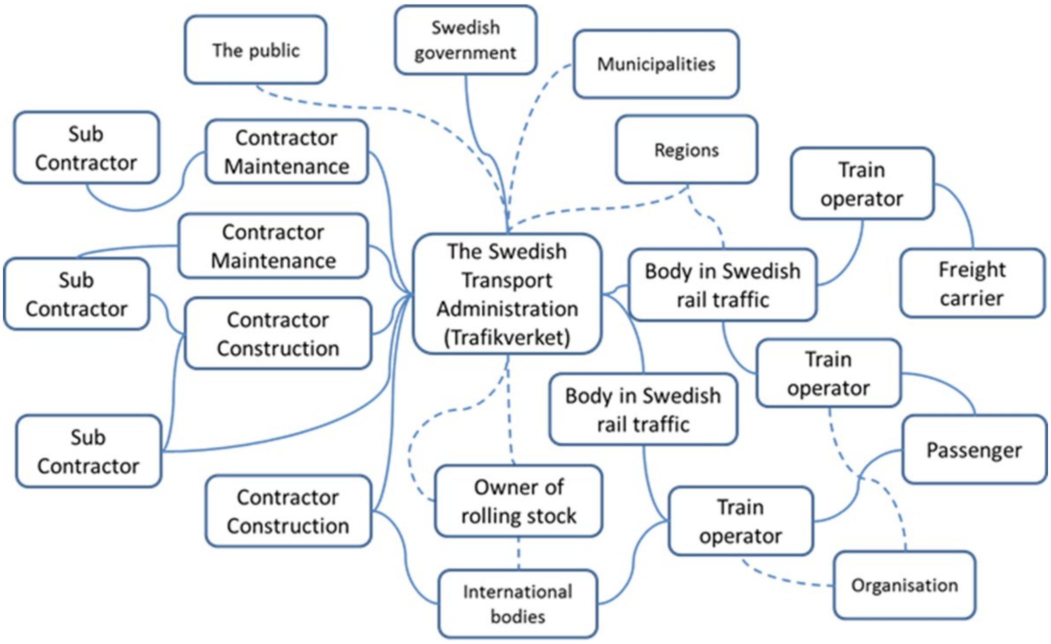

Fig. 3 Business ecosystem, railway traffic in Sweden
Source: [20].

Figure 3 is an example of a graphical model of an ecosystem describing the Swedish railway industry. Formal relationships between the actors are marked with full lines, while the dotted lines denote informal relationships. In this example the most influential actor, the Swedish Transport Administration, is placed in the middle of the graph.

The business ecosystem is not formalized or fixed in context or time; looking at a limited incision of a business ecology at a particular point in time could reveal business structures with different actors of different power, which changes if the viewpoint or time changes. Moreover, a certain business ecology has different meanings for different actors; for some actors it may be central and to others highly peripheral [23]. New actors might enter and others leave, making the business environment of the ecosystem highly dynamic. The business ecology could be large, and thus it is important to define the limitations, identify the key stakeholders, adapt the value offerings according to the stakeholder requirements, and find out which business models and pricing models are the most viable.

Addressing the barriers and reaching benefits through the ecosystem perspective

The use of open data sources is accompanied with technical, organizational and cognitive barriers, which hinders the individual actors from reaching the potential benefits. The global and dynamic market forces different actors within asset management to join competences and collaborate in manufacturing service ecosystems [24].

A huge barrier for achieving this is the distrust between the stakeholders; customers are reluctant to share data with the supplier because they are afraid that their business will be in danger. At the same time, many actors lack knowledge of efficient data management. Extending the business environment by adding a neutral information provider and a regulator could be a way to overcome these barriers. The information provider is an actor with knowledge of data management, while the regulator provides support and control mechanisms for the different actors' behavior, including that of the information provider's [2]. The information provider should be a trusted third party with the purpose of managing the asset information for all involved stakeholders for mutual benefits, such as focusing on the core business and development of new business opportunities. A basic premise is that shared data results in data of higher relevance, accuracy and utility for all stakeholders. But it is hard to distinguish relevant data from the large data sets available. Applying the ecosystem perspective lifts the question of what data is relevant to the full value chain level and beyond [1], thus avoiding sub optimization or contradicting goals. The regulator is responsible for creating and governing the holistic view, for instance in the form of common standards, while the information provider enables this process.

Other barriers can be found in the current information systems. The systems are not designed for data sharing, leading to technical difficulties in identifying relevant data sets, fusion of different data sources and creating a coherent database. In addition, parts of the required data are not recorded in the current systems. Hirsch et al. [24] suggest a service-oriented approach to asset management data in the form of Assets as a Service (AaaS). Assets as a Service can be explained as a virtual representation of tangible and intangible assets that facilitate communication and collaboration between actors in the business ecosystem in the form of generic ontologies. AaaS could be used as the basis for creating a holistic process view, as well as for designing information systems supporting data sharing.

An asset management information example: Swedish railway industry

The Swedish railway industry is characterized by technical, organizational and operational complexity [25]. Within a period of thirty years, the number of actors in the railway transport industry has increased from less than ten to more than a thousand. Technology advancement for the rolling stock, as well as infrastructure and increased capacity utilization have added to the complexity. The complexity has affected the railway operations as well as maintenance. The root causes of maintenance-related problems have been connected to three main areas: information handling and management, regulation and control, and lack of key resources [20]. Among the causes are lack of appropriate IT systems, poor reporting structures, passive governmental management, conservative buyer's culture, poor quality charging system, lack of appropriate maintenance resources, incomplete contractor abilities and competence, and inaccurate analysis models. The tendency is that the actors sub-optimize instead of cooperating. Moreover, traditional contract forms and the conservative buyer's culture result in lack of information and knowledge sharing between the actors [26]. The existing asset information model with the major information flows is presented in Figure 4. Information is shared between the direct actors and regulated in contracts, which results in information isles and interrupted flows, for instance between the different Subcontractors. Moreover, there exist separation in working areas as well as life cycle phases, resulting in low information transfer between the actors, such as the Infrastructure maintainer and the Train maintainer. Information transfer within the value chain is also affected. The Train maintainer, for instance, has no direct access to failure reports and feedback from the Freight carriers or Passengers. The actors are reluctant to share information that could have business value, either real or perceived.

In Figure 5, AaaS allows for smooth information flows to all actors, which improves information handling and management by the creation of a common asset management ontology for the specific context.

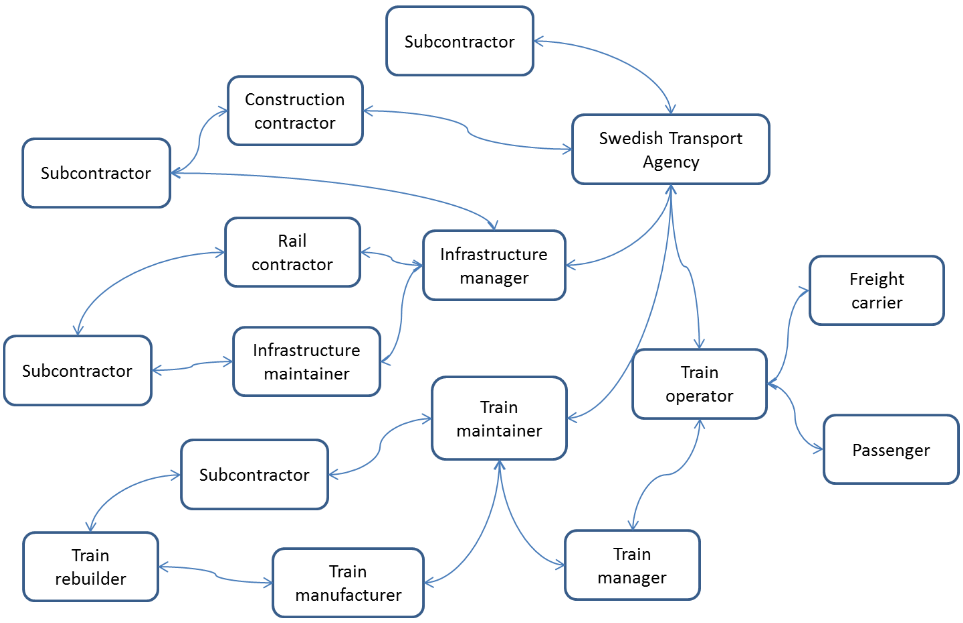

Fig. 4 Existing asset management model

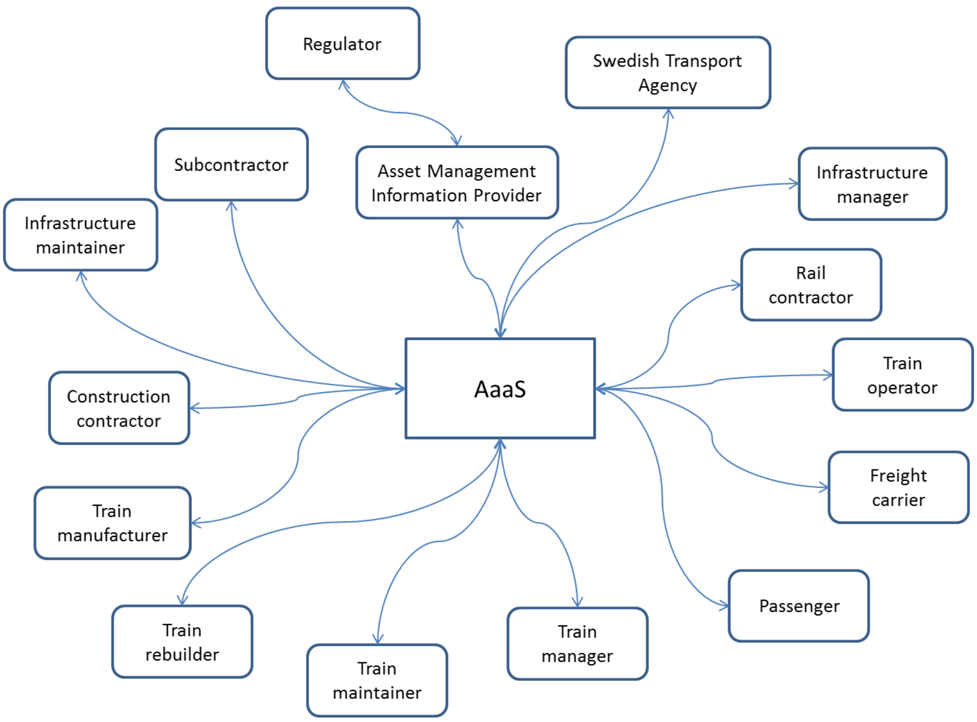

Fig. 5 Alternative asset information management model

The Asset Management Information Provider organizes the data/information fusion and sharing as to which data is shared and with whom it is shared. This way, the data shared by several actors is available in the appropriate format and distribution form, while the safety and integrity of the data is secured. The Regulator assures the relevancy and accuracy of the AaaS ontology with respect to the overall ecosystem objectives, which are to ensure the traffic to move forward with the promised delivery of quality now and in the future [27]. In the case of the Swedish railway, the Regulator should be assigned by the Swedish government.

CONCLUSIONS

Data sharing has a good potential, but the ownership of data is perceived as very important to companies. They do not want to share data with others because they are afraid of harmful use of the data. Another barrier is lack of knowledge to analyze big data. Companies do not identify the advantages of data sharing because they do not understand the data well enough, or the possibilities available in combining data. The maintenance playground is complex and fragmented, and all parties have they own computerized systems, making it hard to orchestrate data flows and data sharing. The new solutions must be suitable for integrating with the manufacturers' equipment. A very large amount of data is collected but it is difficult to define what data should be shared. Many doers are afraid that someone else can have more advantages of the shared data which lead to data sharing is not done enough in companies or between companies. Win-win thinking has not become popular in data sharing, and customers do not understand the potential of new services based on data sharing.

In the future, transparency can be seen as a "sharing economy". The big question is how it can be implemented in a multi-company environment with a positive attitude. Data sharing rules must have been agreed with the partners beforehand. Finding an outside facilitator whom all trust could be challenging. The Asset Management Information Provider is an information manager offering the needed information to all actors with Asset as a Service. The problem of trust between the actors can probably be solved with the AaaS concept. Sharing data can create potential for new business, e.g. new services can be developed, such as remote support, data combination and analysis services, etc. The sharing economy adds transparency, which can work positively between companies and service networks. Better data management can help to make better decisions, and online data enables creating new business models, especially for service providers.

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