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Survey of Big Data Use and Innovation in Japanese Manufacturing Firms

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Survey of Big Data Use and Innovation in Japanese Manufacturing Firms[1]

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Abstract

This paper shows the results of a survey on big data use in manufacturing firms and innovation, conducted in November 2015. The survey investigated (1) firms' organization of big data use, (2) collection and business use of big data by type of data, and (3) use of datasets outside firms, with 539 respondents out of 4,000 firms. We divided the entire manufacturing process into three parts, i.e., development, mass production, and after services, and find that big data are widely used in all activities. In addition, firms with dedicated big data use function are more likely to conduct big data activity across various departments, as well as demonstrate a higher performance impact. However, we also find great disparity in terms of the usage style, particularly by firm size. For example, more than half of small and mid-sized enterprises (SMEs) responded that they have heard of Internet of Things (IoT), yet they are unaware of how to respond to such trend. Policy implications based on the results include (1) promoting diffusion of big data use, particularly for SMEs, (2) supporting human capital development for big data use, and (3) strategic standardization activities of IoT.

Keywords: Manufacturing, Big data, Internet of Things (IoT)
JEL classification: L60, O33

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1. Introduction

The way of manufacturing has significantly changed due to the progress of internet technology. The government's “White Paper on Manufacturing Industries (Monozukuri)” has also warned that IoT (the Internet of Things: all information about a device is connected to the internet) has become the global trend, and manufacturing innovation using such technology is an urgent task for Japanese companies (Ministry of Economy, Trade and Industry, Ministry of Health, Labour and Welfare, and Ministry of Education, Culture, Sports, Science and Technology, 2015). The spread of the internet and various sensor technologies has allowed data collection and accumulation at each level of design, development, production, and after-sales services of goods (products, components, materials, etc.), which can lead to new businesses. In Industrie 4.0 (the Fourth Industrial Revolution) led by Germany, increasing efficiency of the whole economy and society has been proposed by proceeding with standardization of data formats between companies and realizing data exchange across companies (Motohashi, 2016). Given that the environment surrounding Japanese manufacturing has largely changed, quantitative evaluation of the current status of data use in manufacturing is necessary to study the way of manufacturing in Japan, and apply the results to business strategies or policies of each company. As for innovations with big data, investigations have been documented on data volume or information technology (OECD, 2015; Ministry of Internal Affairs and Communications, 2015), but a quantitative study on the utilization or the effectiveness, has not been available. With this in mind, the Research Institute of Economy, Trade and Industry conducted a survey on big data use and innovation in manufacturing firms, in November, 2015. This paper summarizes the survey and the results.

In this survey, we divided the manufacturing process into three parts, development (before product), mass production (production), and after-sales services (after product), and then investigated the following three points: (1) the current status of data generation and data use in each process, (2) the mutual use of data between sections (for example, the development section uses the data collected by the production section), and (3) collaboration of data use with external companies such as suppliers and customers. We have also investigated the management structure for data use, for example, the presence or absence of a specialized department to promote the use of big data, and companies’ opinions about the development of human resources required for data use in the internal departments facilitating data use. In addition, asking questions regarding obstacles to data use or its effect on business performance, enables us to devise corporate strategies required to effectively use big data and the strategic implications to promote data use for the whole economy and society.

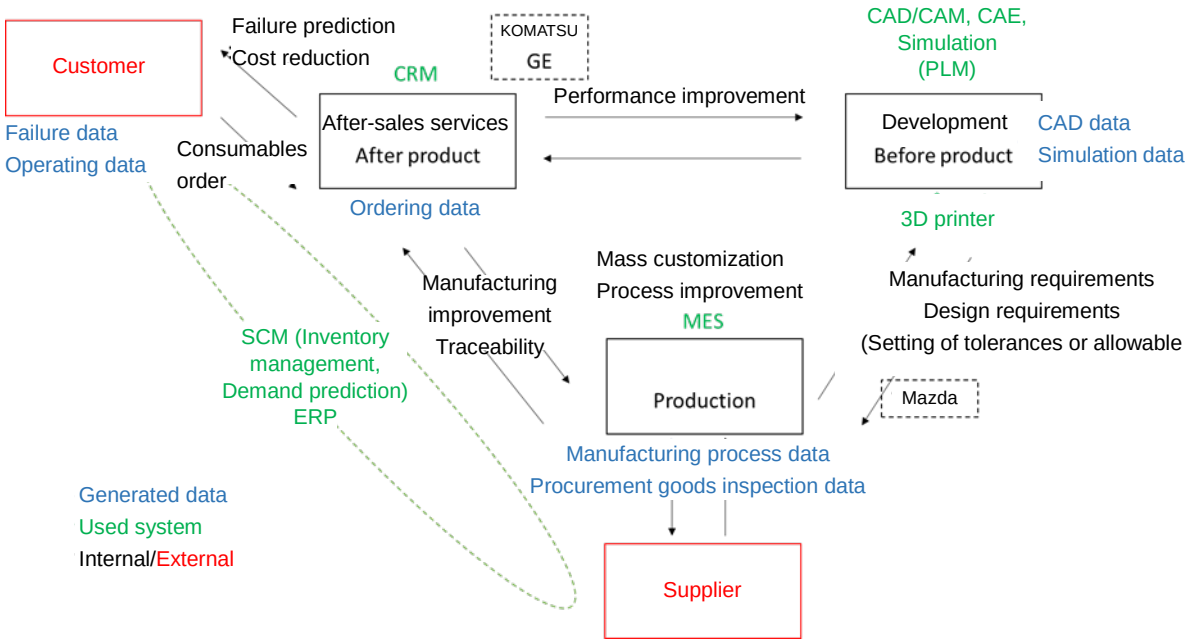
This paper is constructed as follows; chapter 2 shows the framework of the survey to

quantitatively understand the current status of data use and innovation in manufacturing prior to the survey; chapter 3 focuses on the survey content such as questionnaires, target companies, sample designs, and collection rates; and chapter 4 summarizes the survey's results; and the conclusions and implications for both management and strategy are described at the end.

2. Understanding data use and innovation in manufacturing

This chapter shows the framework to quantitatively understand the process from collecting data generated in the manufacturing process, to utilizing the data for innovation such as the development of new products and services. First, manufacturing activity needs to be defined. In this paper, we divided the entire manufacturing process into three major parts, design and development (before product), production of commercial products (production), and after-sales services when products are purchased and actually used (after product). Figure 1 illustrates the data generated in each process and how it is expected to be utilized. Note that the type of data generated is shown in blue and the application name for data processing in green. Data include that obtained through business with customers and suppliers, as well as data generated within the company. Relevant people outside the company are shown in red.

Figure 1: Generated data and the usage in manufacturing



First, the design and development process involves data on simulation results from the development process of new products and on product drawings. The software that creates and manages these data is CAD/CAM (computer aided design/computer aided manufacturing) and

CAE (computer aided engineering). These data are passed on to the production process and used in mass production. The software that manages the product life cycle of each product including user support is called PLM (product life cycle management). As for hardware devices, 3D printers are in place to effectively work on the design and development process.

Next, in the production process, data are generated on the operating status of various manufacturing equipment and the physical environment. Recording the condition in which each product is manufactured helps to identify problems by product unit when defects are found, even in cases of mass production. The software which assures an increase in yields and traceability and improves the manufacturing process by visualization at the production site is called MES (manufacturing extension system). The production process also involves data from suppliers regarding components and materials.

The design and development process and the production process are for sure not independent. The design and development of new products is conducted in accordance with the requirements of the production side (manufacturing requirements) such as production cost or yields. On the other hand, the design and development department discloses information on tolerances in the production process. Although errors always occur in physical processing operations, reducing the errors within an acceptable range is crucial to fully realize product functions. Therefore, conducting close communication between the departments based on objective data is important. For example, Mazda analyzes details and manufacturing process data at production plants of engines and utilizes the results for the development of new engines (SKYACTIV). Mazda also adjusts the amount of engine components by unit, and controls the capacity of the combustion chambers of high-compression engines to realize low fuel consumption (“Nikkei monozukuri (the solutions magazine for design and manufacturing)”, July 2013 issue).

Finally, the service process involves data on customer information and orders, and these data are managed by a system called CRM (customer relationship management). The service section also receives information on the operating status or equipment failure at customer sides. For each product defect, management of the manufacturing process data by unit helps to identify the cause and take measures (improvement of traceability). In addition, the structural results are fed back to the development process of new products in the design and development section.

Collecting data on the utilization status of a customer’s equipment enables improvement of the service level for customers. Komatsu attaches a GPS or various sensors to their construction machinery to offer various services such as informing clients of the need to replace consumables,

or supporting energy saving operations (Kinukawa et al., 2015). Similarly, GE analyzes the operation data of their jet engines to offer maintenance services to air transport companies.

For data collaboration with business partners, including customers and suppliers, CRM and SCM (supply chain management) have been conventionally used and are available as an ERP (enterprise resource planning) package to manage internal and external management resources. Recently, in addition to these systems, the improvement of sensor technologies and the reduction of prices have enabled more detailed and timely data collection, and more advanced types of data use. Thus, in order to grasp the status of data use in manufacturing, it is important to obtain the information on the frequency and start period of data use, as well as to monitor data generating sections and data using sections by data type.

3. Contents of the Survey

3.1 Survey items

The questionnaire consists of the following four parts:

- Company profile
- Structure and organization of data use
- Status of data collection and utilization by internal sections
- Utilization of external data

First, we asked about the “Company profile (the presence or absence of group companies, company size, major business, business type such as B2B or B2C),” followed by a question on the “Structure and organization of data use.” In this survey this item was included as it was recognized that investigating the internal organization is also important to enhance business value by using data, as well as grasping the current status of data use. This part covers the presence or absence of sections to promote company-wide data use, the name of the sections using data, the position of the person in charge of data use, the number of relevant staff, and frequency of data analysis. The item regarding required human resources to create business value from data use was also included in the survey.

The items, “Internal data collection and utilization status” and “Utilization of external data,” are based on the framework described in chapter 2. We divided the manufacturing process into three parts, “design and development,” “production,” and “after-sales services,” and investigated the various data generated in each process from the source, and the sections using the data by data type. For external data, we mainly reviewed the data exchange

between business partners including customers and suppliers.

3.2 Designing a target sample for the survey and collection status

Since this survey focused on data use in manufacturing, manufacturing companies were selected as the target. To design a target sample for the survey, large companies of a certain level in size, and small and medium-sized companies that are engaged in leading initiatives for manufacturing were selected. More specifically, a total of 4,209 companies were selected by using three kinds of company lists; (1) all listed companies, (2) unlisted companies with non-consolidated sales of 1 billion yen (reference to 2015 Toyo Keizai's database on unlisted companies), and (3) small and medium-sized companies listed in J-Good-Tech. J-Good-Tech is a business operated by the Organization for Small & Medium Enterprises and Regional Innovation to develop sales channels by conducting matches on the internet, or at business meetings between B2B small and medium-sized companies and customers (mainly large companies).

The survey by mail started on November 20. We sent demand notes to 4,112 companies (non-respondents) two weeks later, and made phone calls, resulting in 592 companies responding (response rate: 14.1%). Note that the survey was outsourced to TOKYO SHOKO RESEARCH, LTD.

The number of samples and collection status by sample type are as follows.

Table 1: Number of subjects and responses to the survey

	No. of subjects	No. of responses	Response rate
Listed company (Manufacturing)	1,493	141	9.4%
Unlisted company (Toyo Keizai)	1,623	172	10.6%
Small and medium-sized company (J-Good-Tech)	1,093	279	25.5%
Total	4,209	592	14.1%

Table 2 shows the number of employees of the respondent companies by sample type.

Table 2: Number of employees of respondent companies[2]

	-20	21-300	301-	Total
Listed company (Manufacturing)	0	38	103	141
Unlisted company (Toyo Keizai)	2	100	69	171
Small and medium-sized company (J-Good-Tech)	94	180	3	277
Total	96	318	175	589

[2] Due to lack of employee information with three of 592 respondent companies, a total of 589 companies are targeted in Table 2.

Table 2 shows that not a small number of small and medium-sized companies are included in the listed companies and the unlisted companies. Note that most of the small companies with less than 20 employees are samples from J-Good-Tech, and most of the companies with 301 employees or more are either listed companies or unlisted companies of a certain level in size. This means that for large companies, we targeted all of the companies of a certain level, while for small and medium-sized companies, we targeted the companies with technological capabilities and those listed in J-Good-Tech.

4. Survey results

4.1 Initiatives for data use throughout the company

First, we show the current status of company-wide data use in manufacturing companies in Japan. The targeted data here describe the data generated in each manufacturing process shown in figure 1. Based on the title of the survey, "Big data use in manufacturing firms and innovation," we believe that respondents answered with more detailed and frequently collected data, rather than small amounts of data used in conventional systems such as SCM or CRM, although that was not indicated in the questionnaire.[3]

Figure 2a shows the proportion of companies by the number of employees regarding whether data use is conducted at company level or section level, or if data use is not conducted. Figure 2b shows the results by size (small; 300 employees or less, large; 301 employees or more) and the companies' business type regarding the same questions as figure 2a.[4]

Note that company-level data use means there are departments or sections using data throughout the company, and section-level data use means some sections use data but not at company level.

(Figure 2a), (Figure 2b)

[3] Valid data size varies depending on survey purposes or industries, and to define big data by size is difficult. Based on such limitation, big data is considered to be the data bigger than dozens of terabytes or petabytes in some cases. (Mckinsey Global Institute, 2011)

[4] The definition of small and medium-sized company in manufacturing is a company with 300 employees or less or with capital of 300 million yen or less. Accordingly, a company with 301 employees or more could be classified as a small and medium-sized company in accordance with capital requirements. Note that in this paper, we classified a company with 300 employees or less as a small and medium-sized company and a company with 301 employees or more as a large company for the convenience, but this is not precise definition.

Looking at samples of large companies, approximately 20% of them are classified as company-level data use, approximately 60% section-level data use, with approximately 80% of companies use manufacturing data in some way. The data utilization rates decrease with company size. By business type, the proportion of companies engaging in company-level data use are highest in large/B2B end product companies, followed by large/B2B material companies, and the proportion is relatively low in B2B component or B2C business companies.

Figure 3 shows which sections use data by business type in data use companies. In all business types, sales sections use data most often, followed by the research and development section, the management and planning section, and the production section. In B2B end product companies, the proportion of research and department sections is relatively high, in B2C companies it is the management and planning section, and in B2B component companies it is the production section that is relatively high. B2C companies are characterized by a relatively higher proportion of marketing and service sections.

(Figure 3)

Figure 4 shows the relationship between internal data use level and external data use. The companies with frequent use of internal data are more likely to use external data, and a positive relationship is found between the internal and external data use. Although external data include two kinds of data, customer data and supplier data, more companies use customer data.

(Figure 4)

In order to effectively proceed with data use in manufacturing, taking systematic initiatives throughout the company and not by section is important. To do that, there are several approaches including commitment of the management or headquarters to data use in various ways, in addition to establishing a company-wide data analysis department. Figure 5 shows the details, and more than 50% of companies engaging in company-level data use answered that they include the items on data use in their mid-term management plan. This proportion exceeds 40% even in the case of companies engaging in section-level data use, indicating that data use is an important matter for management strategy in many manufacturing companies in Japan. There is a big difference between companies engaging in company-level data use and those in section-level data use, regarding the internal

sharing of data analysis skills, and the establishment of a department specialized in data analysis. Also companies engaging in company-level data use work on data use more systematically.

(Figure 5)

Figure 6 shows the human resources required for data use. For data use in business, various abilities are required including technical skills such as programming or statistics, business knowledge about business practices or business model analysis, and communication skills, for the communication between IT sections and business sections (Davenport, 2014). There was no big difference found between companies engaged in company-level data use and those in section-level data use, on which skill is especially important out of those previously mentioned skills. Data analysis skills and data interpretation skills are considered to be the most important, and the proportion of companies that require business knowledge, communication skills between different sectors, and programming skills, is low.

(Figure 6)

In connection with the above, figure 7 shows the survey results on obstacles to data use, indicating the biggest obstacle is a shortage of human resources. Once again, a number of companies consider the lack of human resources with business skills (related to data interpretation skills in figure 6), and those with data analysis skills, as an obstacle, and the proportion becomes higher in the companies with higher levels of data use. This means that once data use progresses, the human resources required or skills, becomes clearer, and the gap with the current status also becomes more apparent. On the other hand, companies with lower levels of data use have high rates of absence of collection or accumulation systems, highlighting the problem that those companies are not making systematic efforts at the company level. Except in companies where data use is not necessary, it is important to allocate business resources to data use first and take action.

(Figure 7)

Finally, we show the survey results on the initiatives for innovative data use such as the collaboration of various systems, utilization of 3D printers, or IoT (internet of things). As shown in figure 8, a relatively large number of companies have been working on single

applications such as utilization of sensors in design and development simulations, or in the production process, but only a few companies have been conducting system connection or integration including connection of a new system, such as PLM or equipment monitoring, with ERP that involves management of the business resources of the entire company.

(Figure 8)

Figure 9 shows the initiatives for IoT by size and companies' business type. Note that IoT is defined as activities in which the flow (production, after-sales services, etc.) of the goods, such as each product, component, or material, is stored as data, using for example sensor information, and the data are used to add value in business. As a whole, approximately 10% of companies have already been working on IoT, while less than 10% of companies answered they know about IoT but have nothing to do with it. Although IoT has been recognized as a concept that could have a major influence on the entire manufacturing industry irrespective of the size or business type, more than half of the companies answered they have heard about IoT but have not taken action yet, and specific approaches have not been proposed. By business type, more the 40% of B2B material/large companies answered they have already been taking measures. As a general trend, initiatives have been progressing in B2B large companies while they have been delayed in small and medium-sized companies.

(Figure 9)

4.2 Current utilization status by data type

In this survey, the manufacturing process is divided into three main parts, design and development, production, and after-sales services. We show the survey results on the utilization status of 12 kinds of data generated in each process.

Figure 10 shows which section in the company uses (or does not use) each data. The utilization results demonstrate that CAD data, manufacturing process data, purchase data, and customer complaint data are used in 80% of the companies that use some data. These are fundamental data required in each of the manufacturing processes. On the other hand, although POS data and call center data are used by only half of the companies, this may be because these data are not necessary for B2B companies in the first place. In addition, the utilization rates of material libraries, logistics location data, and operating data of equipment, are relatively low, and these data are probably used in specific business types.

Looking at sections by data type, data are classified as those used by only one section (production section), such as manufacturing process data, and those widely used by three sections of development, production, and services, such as customer complaint data. Figure 11 illustrates sections using each data type. Many kinds of data are used by more than one section. Specifically, information on the customer side such as complaints, product defects, operating status, is available for all sections of development, production, and after-sales services. Information on product functions such as CAD/CAE or material libraries is used by development and production sections, while information on the flow of goods such as POS, logistics and delivery, logistics location, and purchases, is used by the production and after-sales service sections.

(Figure 10), (Figure 11)

Figure 12 and figure 13 show the frequency and the start period of data use. Although there is no big difference found between data types, the usage of each data greatly varies by company. For example, manufacturing process data is used most frequently, but while 20% of companies use the data every hour, 30% of companies use the data once a week or less. There is also a big difference in the start period of data use. While nearly half of the companies have been using data for 10 years now, not a small number of companies have been using the data for less than one year.

(Figure 12), (Figure 13)

Finally, figure 14 shows whether there is a difference between sections using data for company-level data use and section-level data use. The utilization rates of company-level data use are higher than section-level data use for all kinds of data, and also the data are more likely to be used by more than one section. Establishing the system to promote company-level data use allows more flexible and advanced use between the sections, rather than ad hoc data use on site.

(Figure 14)

4.3 Relationship between data use and management effects

The questionnaire in the survey contains questions regarding management effects of data use, which enables us to analyze the relationship between the current status and

organizational structure of data use, and the relevant management effects. Figure 15 shows the relationship with management effects by purpose of data use. Note that, since we asked whether companies defined their purpose at the start, the presence and absence of the effects can be reviewed in connection with that of the purposes.

(Figure 15)

First, the items were defined by their purposes at the start including cost reduction, customer development, manufacturing process improvement, existing product improvement, and business innovation, and those were considered to be effective to a certain degree. On the other hand, although the proportion of companies that listed sales increases and new product development as the purpose at the start were small in the first place, the number of companies achieving certain effects was also relatively small. Companies with definite and specific purposes tend to achieve more management effects, but the possibility of having unexpected effects is low.

Figure 16 and figure 17 show the presence or absence of effects by comparing cases where the purposes were defined at the start, and where no purpose was defined, and also comparing where data use is conducted at company level, and where it is at section level. More than 80% of companies answered they had certain effects on the items that were defined as having a purpose (figure 16). There is not a big difference between company-level data use and section-level data use on this point. As shown in figure 17, a relatively large number of companies answered that using data in the manufacturing process achieved unexpected effects that were not defined as purposes at the start. Those unexpected effects are particularly prominent in customer development, existing product improvement, and manufacturing process improvement. The proportion of companies reporting effects were higher in company-level data use than those in section-level data use. We assume that promoting company-level data use helps to collect various ideas on data use from different sections, resulting in an increasing diversity of data use approaches.

(Figure 16), (Figure 17)

5. Conclusions and implications

This paper summarizes the results of the survey on big data use and innovation in manufacturing conducted by the Research Institute of Economy, Trade and Industry. Approximately 80% of large companies use big data in some way, suggesting that data use is widely recognized among a large number of companies. However, the proportion of companies that have already been working on IoT is no more than 10%, and there is high variability on the actual data use. In addition, the proportion of small and medium-sized companies that have implemented utilization of big data is low. As a whole, there is still a long way to go for many companies in the use of big data in manufacturing.

On the other hand, the companies with company-level departments specialized in utilization of big data (approximately 20% of the total of large companies), have been keeping their leading position by proactively working on internal data use, and data collaboration with external data. These companies are more likely to achieve management effects such as sales increases or cost reductions by using big data, and are characterized as obtaining the unexpected benefits that were not planned at the start. Many companies listed analytical skills and data interpretation skills as required human resources, and particularly companies engaging in company-level data use need those skills at higher levels in their human resources.

As for the implications for business management, first we propose investment decisions are based on optional values with data use. In many cases, the validity of IT investment is determined by evaluating the ROI (return on investment). However, this survey revealed that there are companies that achieved unexpected management effects that had not been planned at the start by using big data. In addition, utility values of internal data are expected to synergistically increase by mutual data use between sections, or by use of external data. Accordingly, it is important for a company to allocate appropriate resources and start utilization of data. Investment decisions should be made taking into account the future optional values of such data.

Next, we propose an establishment of internal organization structures for data use. Establishing a specialized department is crucial to utilize data spread throughout a company as a management resource for the entire company. The companies dedicated to initiatives for data use throughout the company have achieved more management effects than other companies. Particularly, the results were different in the case of unexpected effects (optional values) which were not originally defined as the purpose. This means that changing ad hoc data use by each section to company-wide data use, by establishing a systematic structure, can create more data values including

optional values.

Finally, both skills, data analysis and data interpretation, and focusing on business value, are required in human resources for data use. Data analysis skills can be obtained by external training, but data interpretation skills should be obtained by OJT (on-the-job training) because the contents vary according to the situation in which the company is placed. The combination of the two skills is important, which means external training is necessary while OJT is taking place, requiring systematic efforts throughout the company. Special attention has to be paid to the mutual complementary relationship between the establishment of organization structures, such as a specialized department for data use, and the development of human resources.

As for strategic implications, it is important to help raise the level of data use in particularly small and medium-sized companies that lag behind in this area. The progresses of IoT and Industrie 4.0 are highly likely to promote reorganization of supply chains in small and medium-sized companies as well as large companies. On the other hand, more than half of the companies answered that they have heard about IoT, but have not taken any measures yet, highlighting the situations in which many small and medium-sized companies do not know how to deal with this. Activities to provide information should be conducted, by for example, introducing innovative cases, or providing manuals on data use. The VDMA (Verband Deutscher Maschinen- und Anlagenbau, Mechanical Engineering Industry Association) in Germany has provided manuals on manufacturing in the Industrie 4.0 era for small and medium-sized companies (VDMA, 2016). Japan should also take effective measures while referring to such initiatives in other countries.

Next, human resource development is another strategic implication. The utilization of big data specifically requires the ability to analyze business structures by scientific approaches. Logical thinking skills are essential to making hypotheses in business and objectively verify them based on the data. In the U.S., STEM (Science, Technology, Engineering and Mathematics) education has been promoted at higher education levels (McKinsey Global Institute, 2011). Promoting education based on scientific approaches in social sciences such as economics or business administration is important.

Finally, initiatives for standardization of data use are required to promote mutual data use between companies. Although EDI (electronic data interchange), the standardization of data exchange between companies, has been focused mainly on ordering information in the supply chain, there is an increasing need for the exchange of more detailed data and big data, such as information on the manufacturing process in a plant, or the operating status of customer equipment. Japan has to

take proactive measures strategically while watching global trends progressing under Industrie 4.0.

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Figure 2a: Data use level by company size

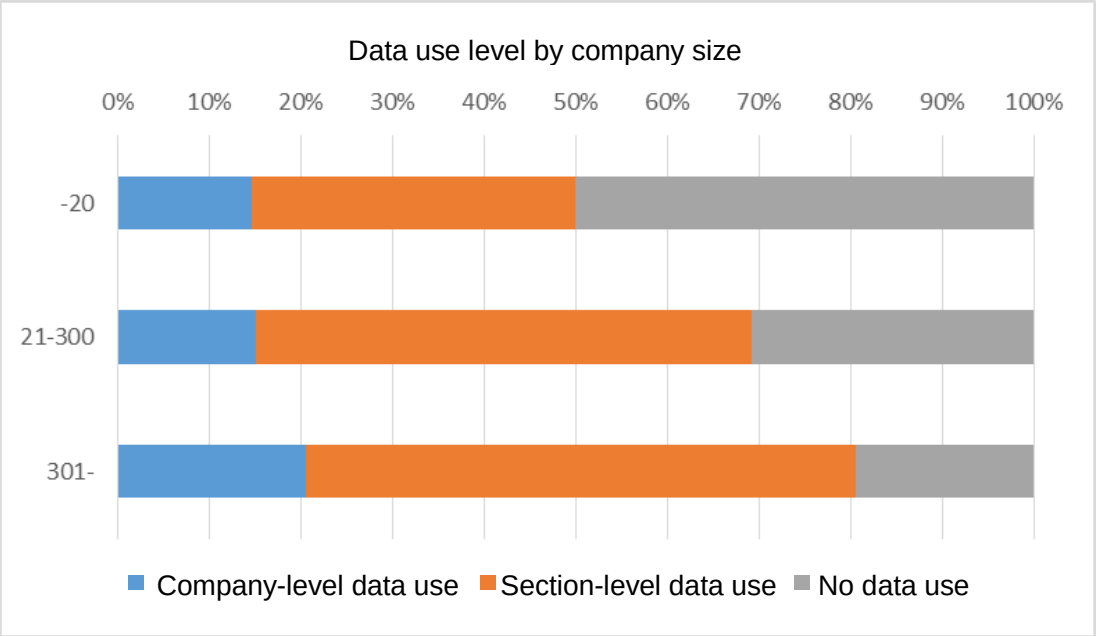

Figure 2b: Data use level by size and business type of the company

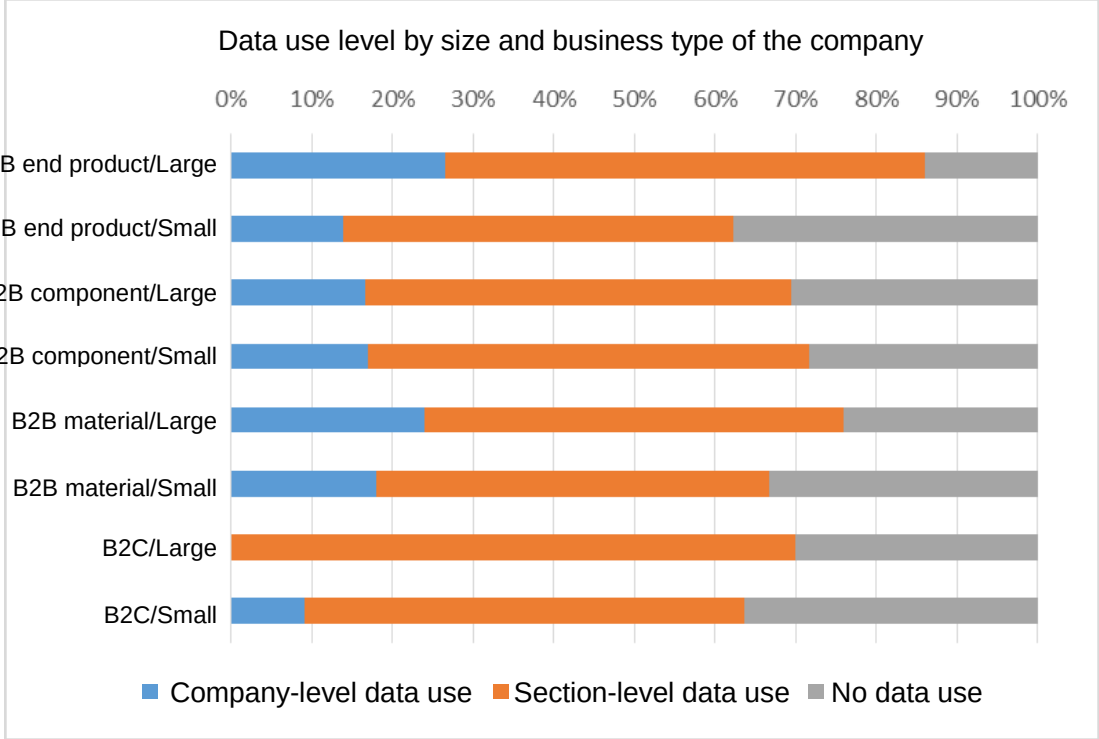

Figure 3: Utilization status by section in data use companies

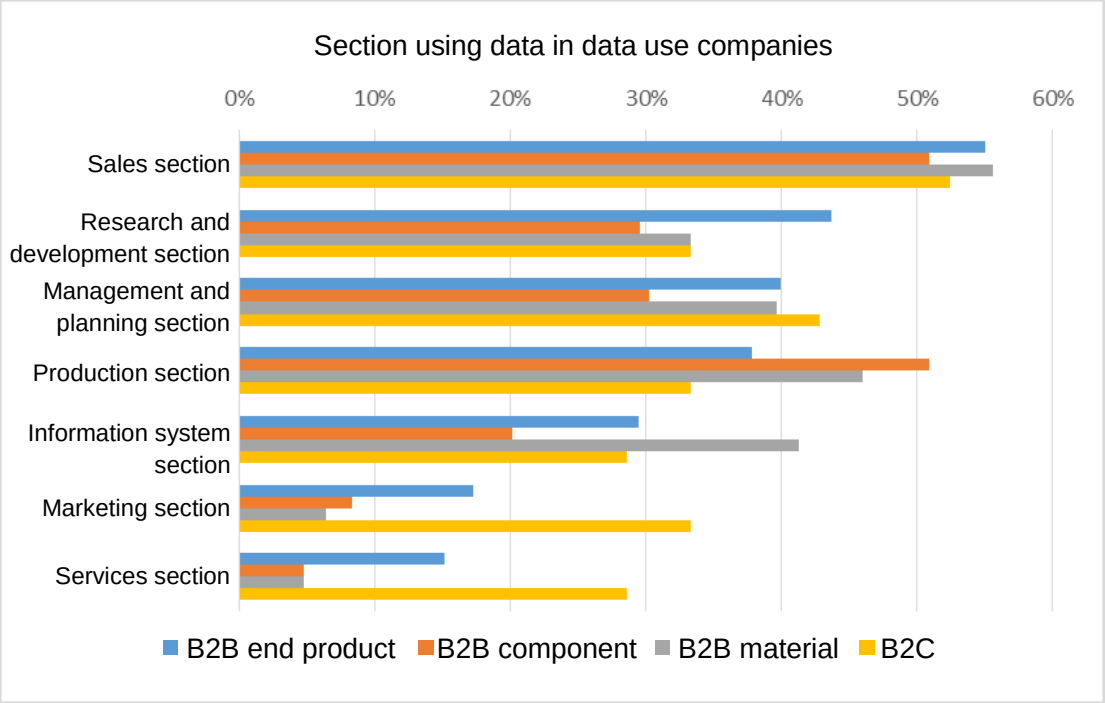

Figure 4: Relationship between internal data use level and external data use

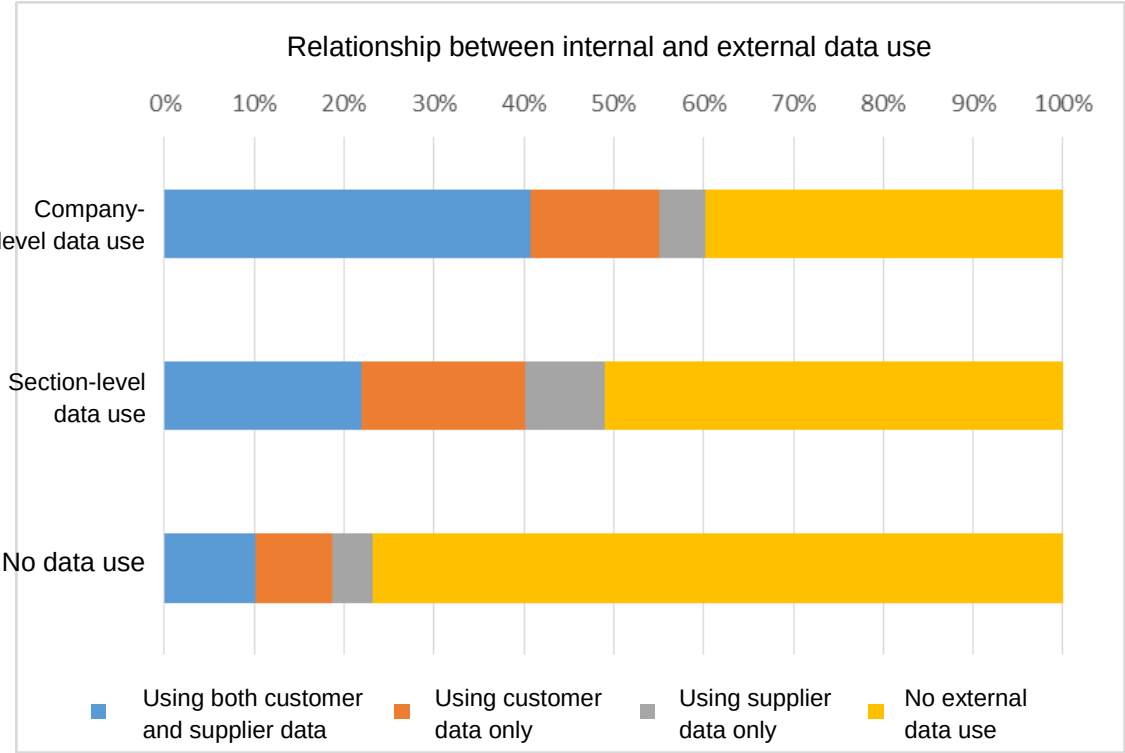

Figure 5: Commitment of management or headquarters to data use

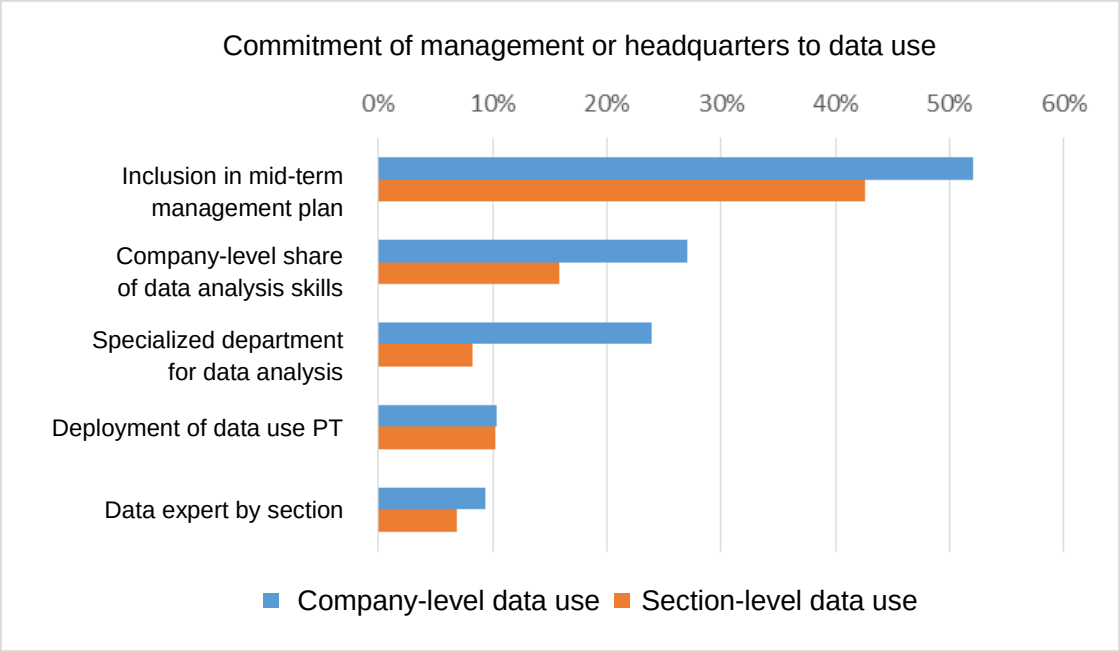

Figure 6: Required human resources for data use

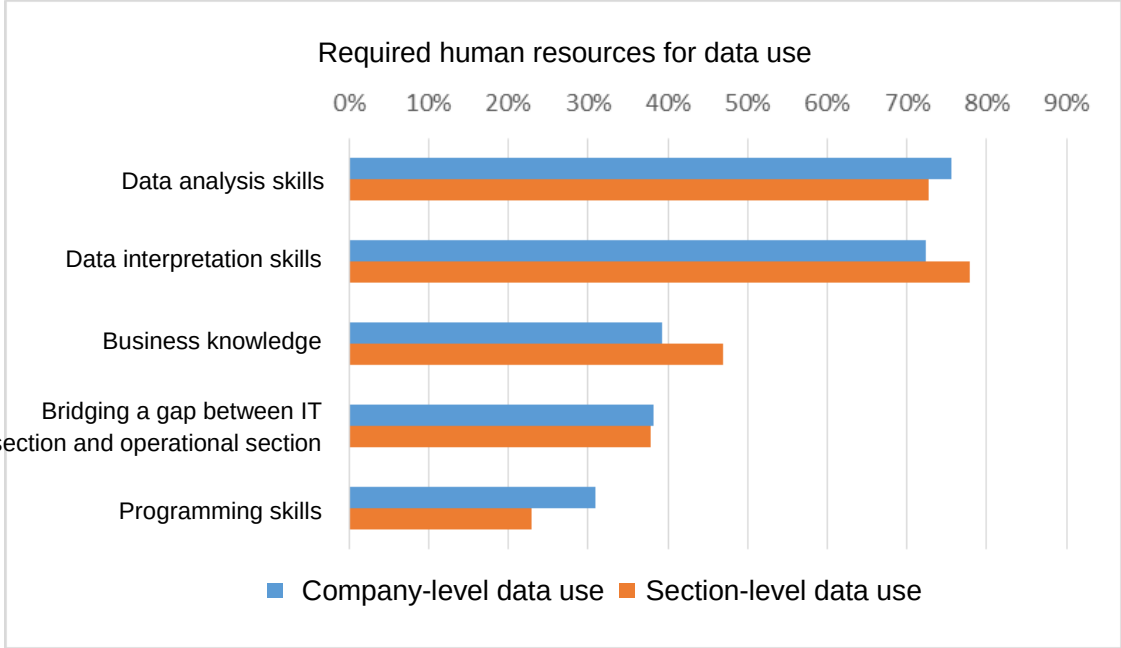

Figure 7: Obstacles to data use

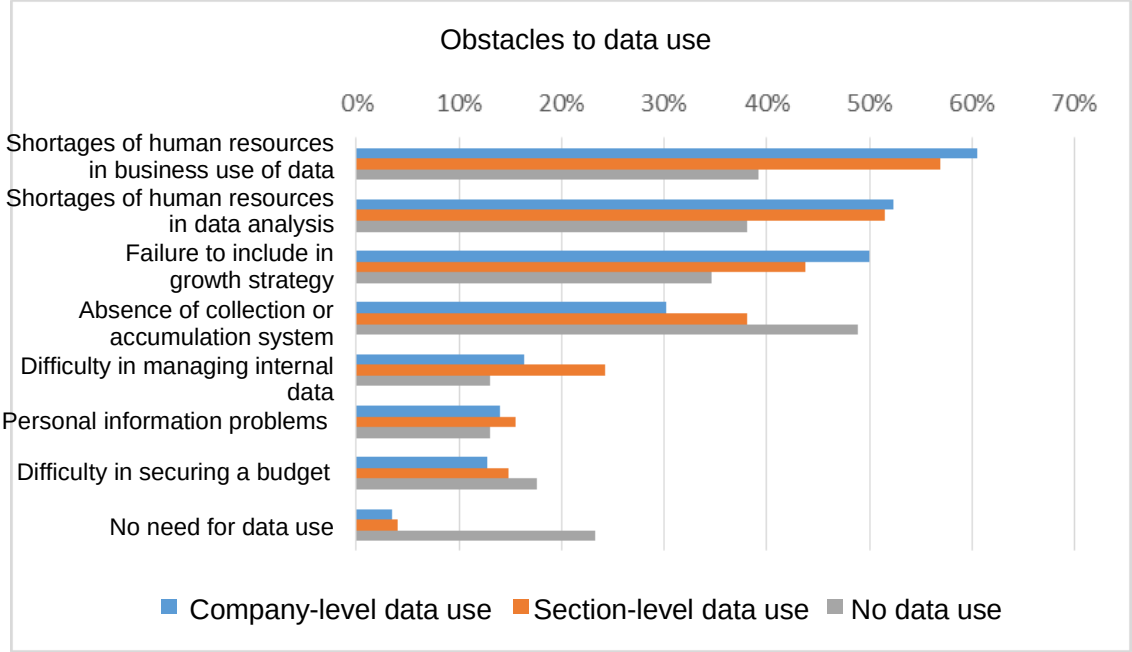

Figure 8: Current status on utilization form of innovative data

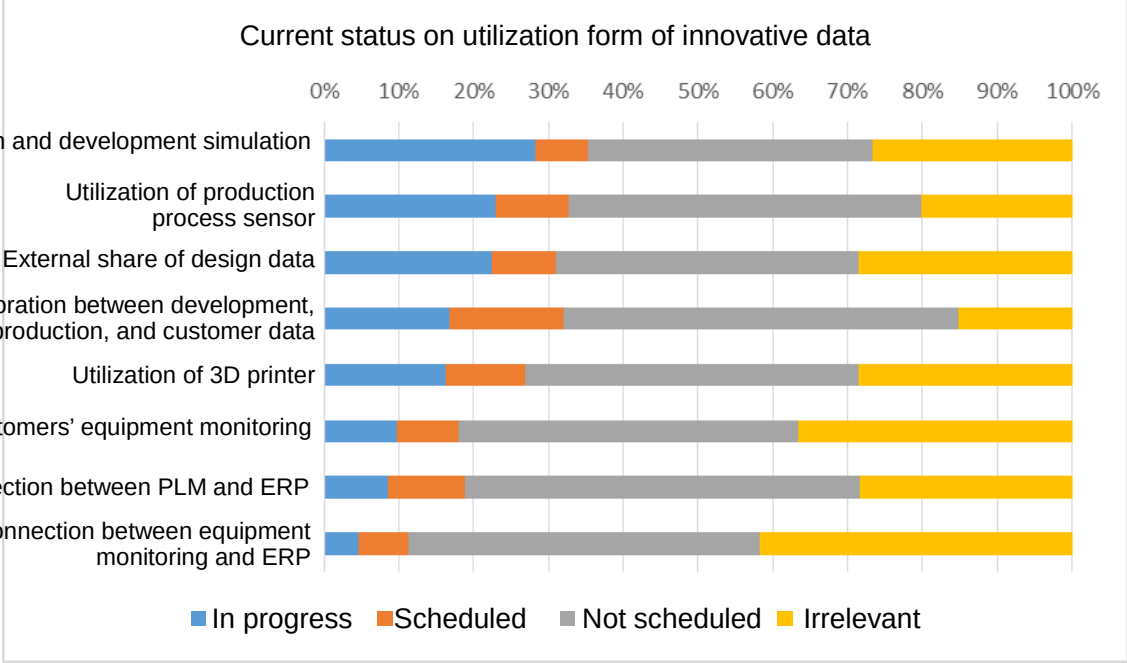

Figure 9: Current status of initiatives for IoT

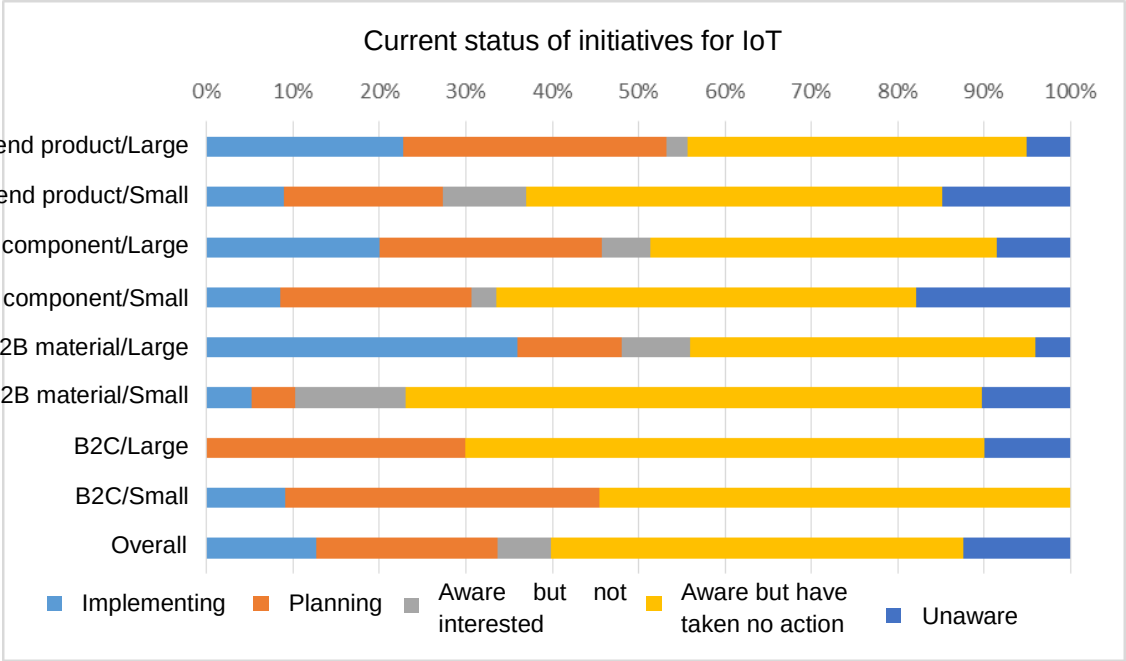

Figure 10: Section using data by data type

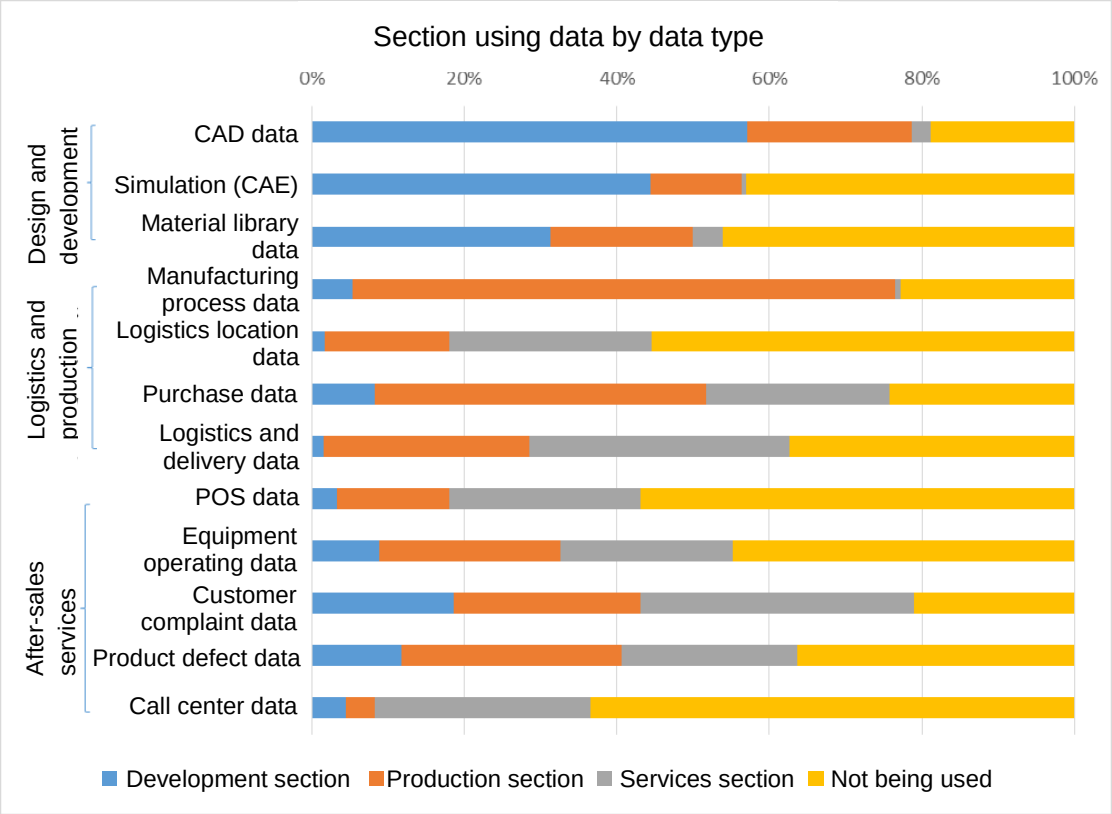

Figure 11: Current utilization status of each section by data type

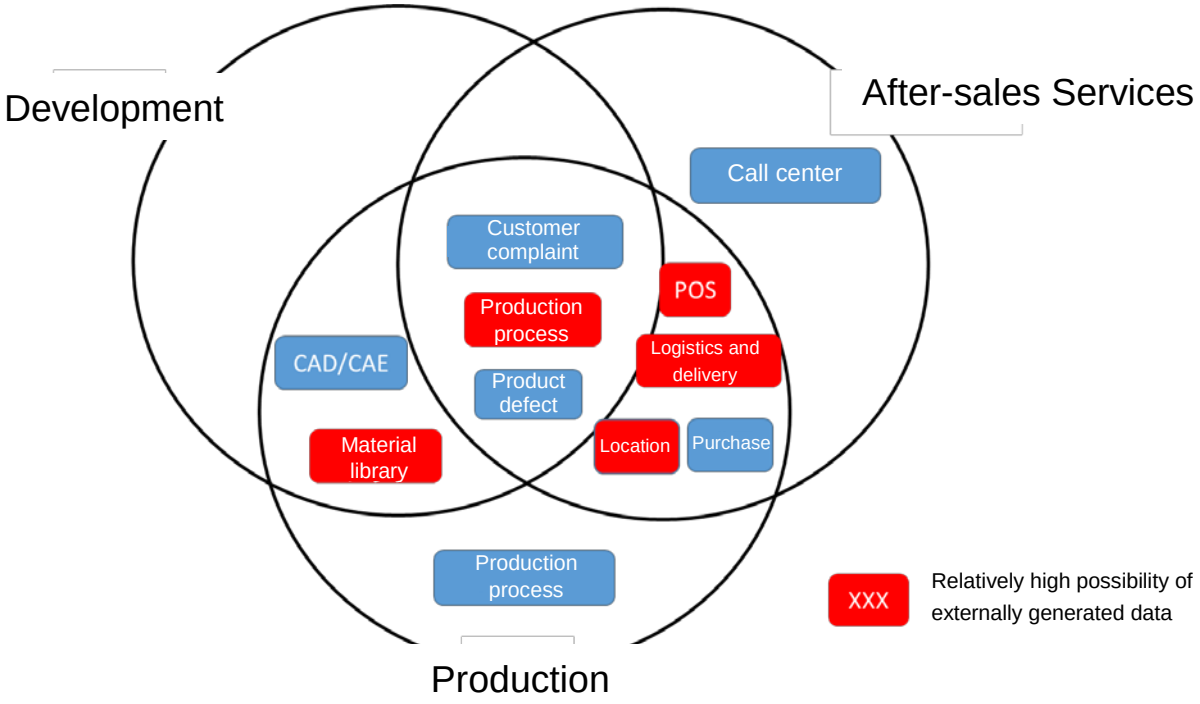

Figure 12: Frequency of data use in manufacturing

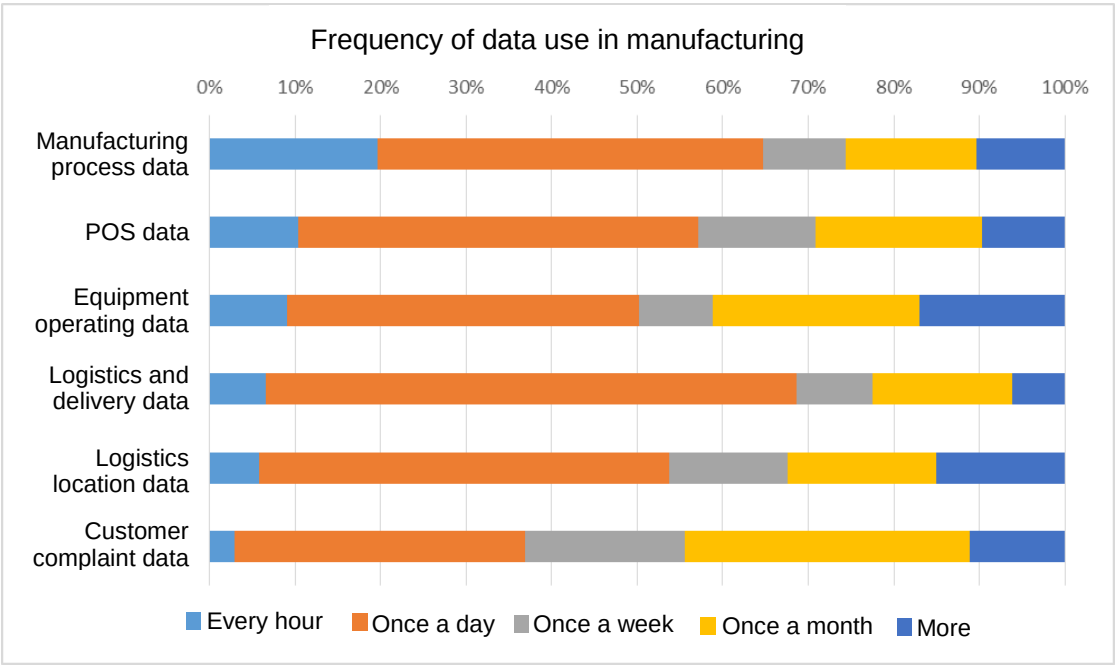

Figure 13: Start period of data use in manufacturing

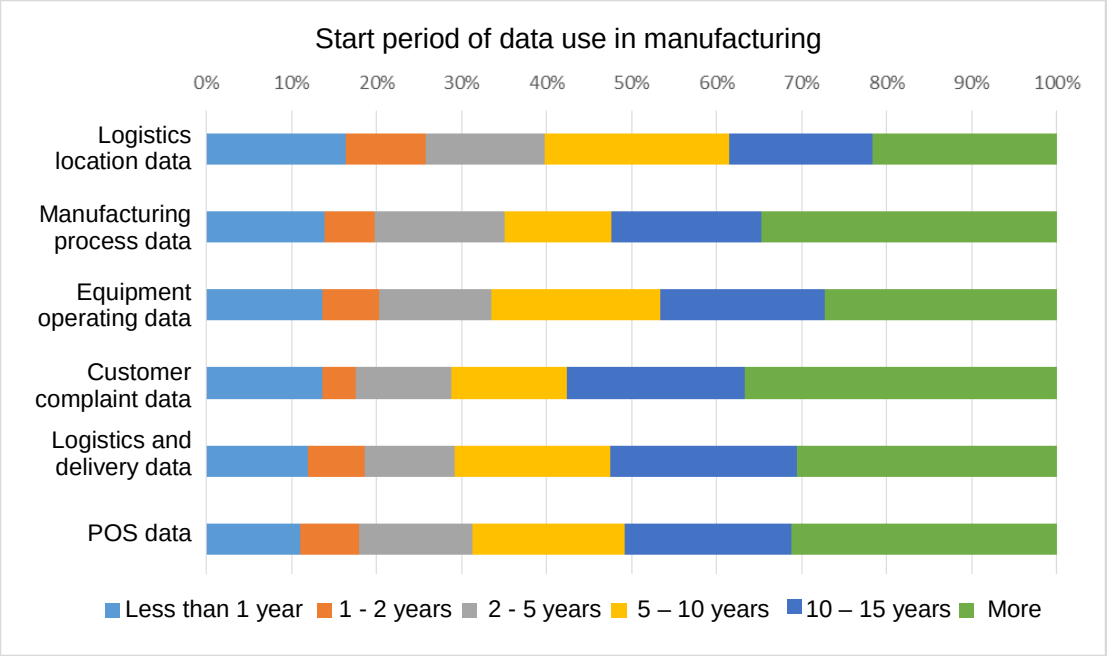

Figure 14: Relationship between data use level of company and number of sections using data

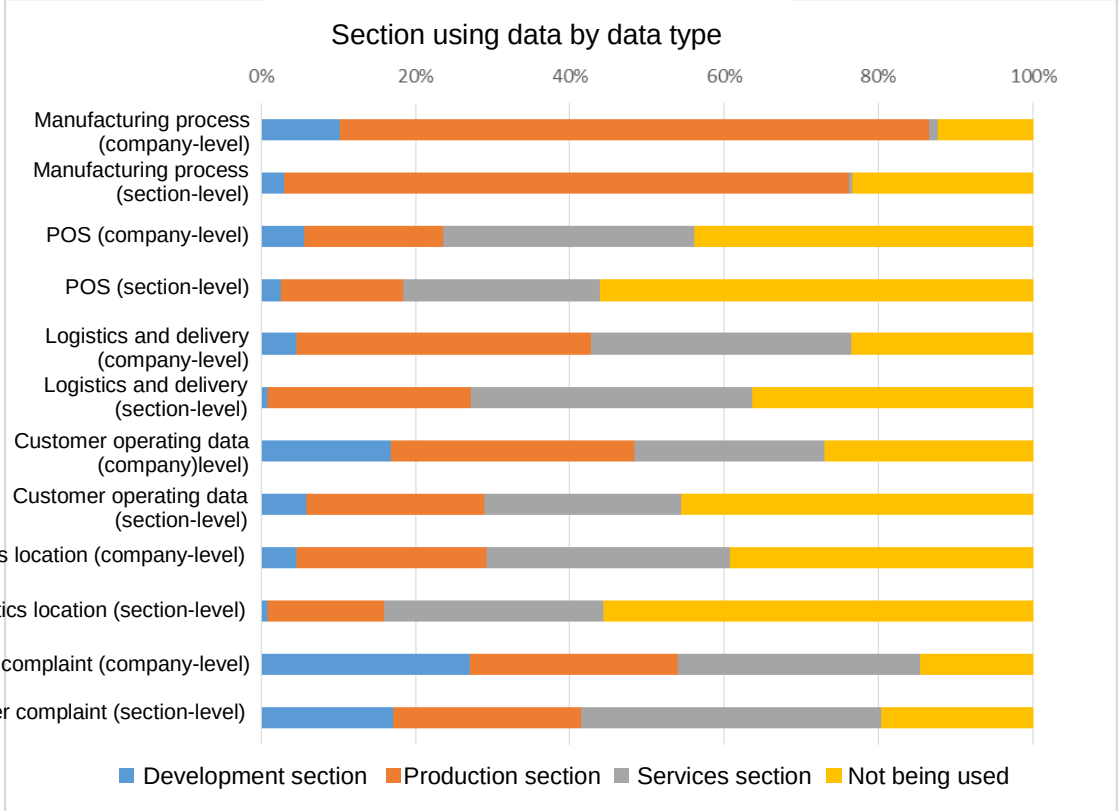

Figure 15: Purposes of data use and presence or absence of effects

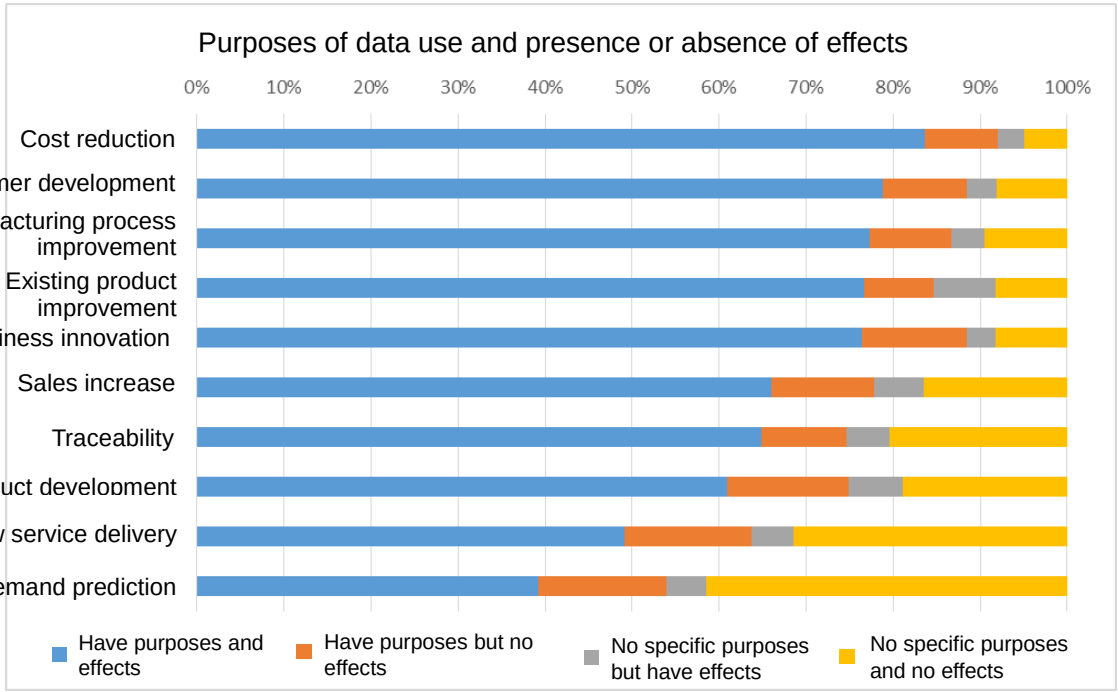

Figure 16: Proportion of companies with effects by data use level (companies with specific purposes)

Figure 17: Proportion of companies with effects by data use level

(companies with no specific purposes)