Agility in Asset Management, or: how to be flexible with assets designed for stability

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Abstract
Agility is increasingly important in manufacturing. However, thus far little attention has been paid to the agility of the physical assets used in production, which are typically designed for decades of operation in a stable context. This paper investigates the topic of agile Asset Management using three case studies. We find that agility may range from asset resilience, asset adaptability and agile asset deployment, in addition to the agility of the Asset Management organization. These findings increase our understanding of agility, and assist Asset Management organizations to accommodate change in an increasingly changeable context.

Keywords: Asset Management, Agility, Flexibility

Introduction
In a world with increasing global competition and ever faster changing customer demands, agility is a very important concept (Santos Bernardes and Hanna, 2009). In the words of Yusuf et al., "[t]he main driving force behind agility is change" (1999, p. 34). Change requires adaptation of the organization and its operations. It is often stated in the literature that only by agility, manufacturing companies can keep a competitive advantage in the current globalized, competitive and consumer-focused markets (Vázquez-Bustelo et al., 2007).

Even though the concept of agility has been coined in 1991 (Yusuf et al., 1999), only recently a broadly accepted definition has emerged. Agility can be defined as "the ready ability to fundamentally change states to accommodate unforeseen circumstances in a timely manner" (Santos Bernardes and Hanna, 2009, p. 42). Agility is conceptually different from flexibility. Flexibility is often related to the property of a system to change within certain (designed) limits (van Oosterhout et al., 2005), for example flexibility as a consequence of holding a stock. Agility includes flexibility but also extends the concept: it is about the ability of a system or organization to reconfigure, in reaction to both anticipated and unanticipated changes (Santos Bernardes and Hanna, 2009).

Agility is most often related to manufacturing and operations (Narasimhan et al., 2006; Sharifi and Zhang, 2001). However, little attention is paid to the physical assets (e.g. machinery) that are used in the manufacturing process. In the agility literature, references to physical assets are scarce. Some authors refer to 'agile technologies' (Bottani, 2010; e.g. Vázquez-Bustelo et al., 2007) or 'flexible assets and systems' (Meredith and Francis, 2000), but they do not study how these assets are agile. Also in the Asset Management literature, the concept of agility is ill-studied (Harris and Carapiet, 2006 is a notable exception). However, many authors have stated that assets and their managers increasingly face change, which they somehow have to cope with (Al-Turki, 2011; Tsang, 2002).

The singularity of these assets in the agility paradigm is their inherent inflexibility: most of these assets are designed to last for several decades. Hence, they see a lot of change in their functional lives and have to be adapted accordingly, even if they were designed for decades of stable operations. The result is an 'agility paradox': organizations have to adapt to changes in their environment, while they are dependent on assets that have been designed for stability. In this paper we aim to explore this agility paradox, in order to contribute to the theory on agility (Handfield and Melnyk, 1998). Additionally, we aim to investigate how the concept of agility can be applied in the field of Asset Management.

Theoretical framework

To investigate agility in Asset Management, we first need to study the main elements of agility, using the distinction between agility drivers, enablers and performance (Vázquez-Bustelo et al., 2007): the need for agility is driven by agility drivers, agility is enabled by certain enablers, which may lead to agile performance. Figure 1 shows the theoretical framework used for this study, which will be explained in the remainder of this section. To guide this study, five propositions will be presented based on this theoretical framework.

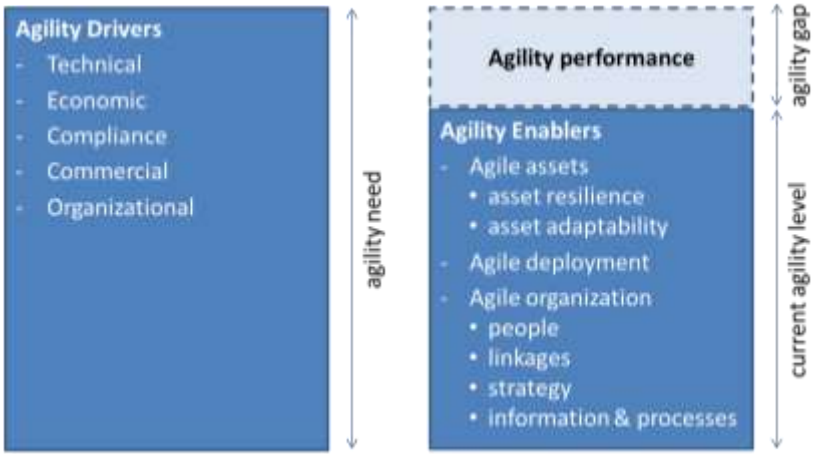

Figure 1 – theoretical framework of agile Asset Management

Agility drivers

As we stated in the introduction, "[t]he main driving force behind agility is change" (Yusuf et al., 1999, p. 34). In the field of Asset Management, the anticipation of change is important to secure the value creation potential of the assets. In an earlier publication, we have

listed five different categories of change relevant to Asset Management: technical, economic, compliance, commercial and organizational (TECCO) (Ruitenburg, n.d.; Ruitenburg et al., 2015). In Table 1, these five categories are compared to those found in the agility literature. These can be mapped on TECCO, except for the economic category. However, the economic category relates to the costs of using an asset, which is clearly related to the agility drivers now categorized as commercial change. As the five TECCO categories have been found to fit the Asset Management context, these will be used to operationalize 'change'.

Table 1 – categories of change that may drive agility (Cp: compliance, Cm: commercial)

Ruitenburg et al. (n.d.; 2015)	technical (T), economic (E), compliance (Cp), commercial (Cm), Organizational (O)
Sharifi & Zhang (2001)	technology (T), social factors (Cp), marketplace (Cm), competition (Cm), customer requirements (Cm), complexity (not explicitly mentioned) (O)
van Oosterhout et al. (2005)	technology (T), social/legal (Cp), business network (Cm), competitive environment (Cm), customer needs (Cm), internal drivers (O)

Agility enablers

The higher the amount of change, the higher the need for agility. Agility enablers allow an organization to be agile. In the literature, little attention is paid to the agility offered by physical assets. To remedy this deficiency, we will investigate agility ranging from the physical asset, from the agile deployment of assets and from the agility in the organization.

Agile assets

In the engineering literature, a few authors have touched upon agile assets. One example are Schapiro & Henry (2012), who start their paper with the assertion that assets "are faced with an evolutionary operational deployment environment in which the problems the initial [design] sets out to address often evolve to areas that the […] design falls short of addressing, or misses altogether" (p.1). Changing operating conditions, which is only one kind of change an asset may have to cope with during its life, give rise to a need for agile assets.

Based on the definition of agility and its relation to flexibility, asset agility may range from two different sources: the inherent flexibility of the system to change within certain (designed) limits, and the possibility to adapt the asset to fulfil functions not anticipated in the initial design. We will term the first aspect 'asset resilience', and the latter 'asset adaptability'. Asset resilience may for example follow from robust designs (Park et al., 2006), allowing the asset to thrive under conditions more severe than anticipated. Or it may range from excess capacity built within the asset (Kogut, 1985), which allows the asset to be used more intensively. Asset adaptability may follow from the modularity of the asset (Ulrich, 1995), especially when the modules that are likely to be impacted most by changes can easily be replaced (e.g. by more innovative or more robust modules).

Because asset resilience is flexibility within certain predefined boundaries, we propose that anticipated change is reflected in the resilience of the asset [proposition 1]. Unanticipated change is rather related to the adaptability of the asset, as it is not yet known what changes might be needed in the future [proposition 2]. However, this may not apply for older assets, as modularity is still a relatively young concept in design engineering.

Agile deployment of assets

Not only may the individual asset be a source of agility, when a larger number of assets is used by the company the deployment of the assets may offer another source of agility. Examples may be redundancy (Wenzler, 2005), reserves and the planning of the asset usage (e.g. carrying out maintenance if the need for the asset is low (Celen and Djurdjanovic, 2012)). Therefore, we propose that the more similar assets an Asset Management organization has to fulfil a function, the higher the agility of the organization [proposition 3].

Agile organization

Next to the agility offered by the physical assets and their deployment, the organization may be a source of agility. As this is an exploratory study, we have chosen the relatively simple categorization of agility enablers used by Meredith & Francis (2000) and Brown & Bessant (2003): agile people, agile linkages, agile strategy and agile processes & information. *Table 2* gives a brief description of each of these enablers.

Regarding organizational Asset Management agility, we propose that the higher the unpredictability of change, the more important organizational agility becomes [proposition 4]. This is because we expect it to be harder to adapt the asset to unpredictable change – especially on short terms – than to use organizational agility to accommodate such change.

Table 2 – description of the four organizational agility enablers

Organizational agility enabler	Relevant aspects
agile people	The number of people employed as well as their knowledge and expertise are the main sources of people agility. Among the aspects found in the literature are: job rotation (Vázquez-Bustelo et al., 2007), education (Bottani, 2010), organizational culture (van Oosterhout et al., 2005), knowledge management and learning (Vázquez-Bustelo et al., 2007) and empowerment (Sharifi and Zhang, 2001).
agile linkages	Agile linkages concern the collaborations within and outside the organization (Vázquez-Bustelo et al., 2007). Within the organization, the literature mentions aspects such as team-building (Yusuf et al., 1999) and cross-functional team sharing (Gehani, 1995). Outside the organization, close collaboration with customers (e.g. Bottani, 2010) and suppliers (e.g. Meredith and Francis, 2000) are often mentioned.
agile strategy	Brown & Bessant (2003) describe an agile strategy as one of the attributes of agility: "involving the processes for understanding the firm's situation within its sector, committing to agile strategy, aligning it to a fast-moving market, and communicating and deploying it effectively". We take this to describe an organization's efforts to identify changes (agility drivers) and to translate these into appropriate responses.
agile processes & information	Agile processes and information contribute to the agility of an organization, as insightful data allow for a fast understanding of (potential) problems, while rapid decision-making processes facilitate responses to these problems. The literature mentions aspects such as ICT systems (Bottani, 2010), decision-making processes (Meredith and Francis, 2000) and rich information systems (Vázquez-Bustelo et al., 2007).

Agile performance

The final aspect of agility concerns the performance of the Asset Management organization. To investigate the organization's agility, we will use the notion of the agility gap, used by van Oosterhout et al. (2005): "[i]f businesses find it difficult to cope with major changes, which go beyond their normal level of flexibility, they are faced with an *agility gap* [*italics* in original]" (p.278). Hence, a company is (sufficiently) agile if it is able to cope with changes in a timely manner. Time is also important here, because an organization's

agility may change over time. We assume that organizational agility is costly as it requires investments in excess resources (e.g. in knowledge or manpower), as indicated by Narasimhan et al. (2006). Therefore, we propose that organizational agility will decline if a company does not consider agility to be important enough to put effort into [proposition 5].

Methodology

To investigate agility in Asset Management in practice, we have carried out a multiple case study (Yin, 2014). The three cases were selected based on the high dynamism in their operating environment as well as on the ease of access to the organizations. Table 3 gives the main characteristics of these three cases.

The main data source for this study were semi-structured interviews: in total 9 interviews were carried out in February and March 2016. All the interviews were recorded and transcribed. To enable triangulation (Silverman, 2006), company documents were studied, as well as the data gathered for earlier research. From these data sources, a case summary was written for each case, which was send to the interviewees for validation.

First, we analysed the data case by case (within-case analysis) (Voss et al., 2002) to investigate the relations between the main constructs of our research. Then, we did a cross-case analysis, to see if the findings from the three cases confirmed our propositions.

Table 3 – main characteristics of the three cases

company name	**Defence Materiel Organization (DMO)**	**Netherlands Railways (NR)**	**Liander**
description	The DMO of the Royal Netherlands Defence ensures that military personnel has modern, robust and safe equipment to work with.	The NR aims to offer easy, fast, safe and affordable travel in comfortable trains for 1 million travellers each day.	Liander is responsible for the construction, maintenance and operation of the electricity and gas grids, to ensure safe and reliable energy transportation.
type of assets studied	land-based wheeled vehicles	rolling stock	the electricity grid
expected lifetime	10 – 30 years	30 years	40 – 60 years
reason for selection	the Army never knows where the next mission will be, funding is highly dependent on (changeable) politics	customer demands change rapidly, political decisions may have significant impacts, the introduction of new trains requires flexibility	due to ageing assets and the energy transition (changes in production and consumption of energy), its stable operating conditions may change rapidly
# of interviews	4	2	3
additional data collection methods	study of company documents	study of company documents, interviews for earlier research	study of company documents, ongoing action research

Results of the three cases

Agility drivers

The three Asset Management organizations studied all operate in a changeable context. Table 4 lists the main sources of change for each case company. Notably, even though Asset Management is often considered a predominantly technical and financial discipline, the

main changes do not range from these backgrounds. Rather, changes in customer demand and organizational decisions are the main cause of change resulting from the cases.

Regarding the development of change, the DMO acknowledges that obsolescence of (electronic) components is a growing issue that needs to be accommodated. The NR also recognized an increasing changeability, mainly on customer demands and the influence of the Dutch government: "there things go faster as well, more dynamic, with larger deviations". The Liander respondents had different opinions on the development of change. One of them thought changeability will remain the same, while another stated that "we realize that the energy transition develops non-linear and highly unpredictable". Probably, this disagreement results from the uncertainty about energy transition still existing within Liander.

Table 4 *– overview of the main drivers of agility (shaded cells indicate the main agility drivers)*

Agility drivers	**Defence Materiel Organization (DMO)**	**Netherlands Railways (NR)**	**Liander**
Technical	obsolescence of parts, mainly electronic components	introduction of trains, obsolescence of parts (mainly electronic)	ageing assets, new failure modes caused by the energy transition
Economic	budget cuts (issued by the government), budget allocation dependent on large projects	corporate strategy changed from purely financially driven to a broader strategy	available budget (regulated by the government), rising costs of using public space
Compliance	no important changes	stricter regulations (e.g. safety, noise and environment), obligatory changes (e.g. new braking system), government decisions (e.g. public transport card for students)	regulation (e.g. safety, but also related to the energy transition), social acceptance of noise and visibility of the assets
Commercial	user demands change as a result of different mission characteristics (climate, exposure to specific dangers)	number of travellers (incl. winning contracts to operate lines), services required by the travellers (e.g. air conditioning, Wi-Fi)	quantity of demand for electricity and gas, need for new functionalities (related to the energy transition)
Organizational	deployment on missions, tasks assigned to units, decisions to extend lifetime of vehicles, the need to implement new technologies (e.g. communication)	no important changes	strategy regarding the future of the gas grid, new focus in Asset Management
Development	increasing (slightly)	increasing	internally debated

Agility enablers

The three case studies yielded a large number of different ways in which these Asset Management organizations were able to be agile, which are listed in Table 5.

Asset resilience is about the inherent properties of the asset that allow it to function under different circumstances without any need to adapt the asset, and ranges from the initial design of the assets. In certain cases, this is done deliberately: the trains of the NR are designed for longer lifetimes and heavier loads than initially needed. In other cases, this asset resilience is less intentional. Liander offers an example: up to some 20 years ago assets were bought with a design life of 25 years, while they have been found to easily last for 40 years. Amongst others, this is caused by the conservative designs of the asset developers.

Regarding the *adaptability of the assets*, the picture is mixed. At DMO and the NR, most assets receive a midlife update (MLU) to extend the life of the assets and to add new functionalities (e.g. at NR air conditioning has been retrofitted into all older trains). While the MLU is more or less standard for their assets, the assets are not designed for easy adaptability. At Liander we get a different picture: when the complete grid is considered as one big asset, its modularity is reasonably high. However, its adaptability is then limited by its geographic dispersion and large numbers of assets (e.g. 45,000 distribution transformers).

The third level of Asset Management agility can be found within the (deployment of the) *asset population*. The best example is offered by the strategic reserve of the NR, which consists of a number of trains that can be made ready for deployment within a few months (mostly trains close to their end-of-life). This strategic reserve is currently empty due to challenges with the introduction of a new train and an increase in travellers, but one of the respondents added: "I was *tremendously* happy that we *had* it by now [original emphasis]," as otherwise there would currently be a large deficit in transportation capacity.

The final type of Asset Management agility lies in the agility of *the organization*. All four types of agility were mentioned during the interviews, although the agility in information and processes was less pronounced than from people, linkages and strategy. For each aspect of organizational agility, one example will be given from the case studies. Table 5 gives a more complete overview. Regarding the agility of people, the DMO stressed the 'make it happen' mentality within the organization: everyone is aware of the importance to have "our men on the missions with the right equipment." Collaborations within the organizations are important (e.g. between user and maintainer), but also those with external partners. These are primarily partners that have complementary knowledge on the assets (e.g. suppliers), but Liander also has close collaborations with (local) governments and institutions to get a better understanding of the energy transition, as well as to try to influence its development (e.g. by setting a standard for electric vehicle chargers). At the NR, the fleet management process is their main strategic agility enabler. In this process, they compare prognoses of the future transportation demand under different scenarios with the expected availability of their trains. Even the demand in the highest scenario should be realizable. To allow this, the fleet management plans list a number of options, including a decision calendar when choices need to be made. In this way, they prepare for very different futures and postpone the actual decisions to the latest possible moment. Regarding information and processes, Liander is trying to get a better understanding of the energy consumption of individual households, to make better use of the existing asset capacity.

Table 5 *– overview of the main agility enablers*

Agility enablers	**Defence Materiel Organization (DMO)**	**Netherlands Railways (NR)**	**Liander**
Asset resilience	some of the vehicles either have intentional excess capacity or are overly robustly designed, in the asset design the possibility of life extension is not taken into account	all trains are designed for lifetimes of 30 years, while their expected service life is 20 years (this allows life extension). Trains are designed in such a way that an extra car can be added	the electricity grid is constructed to facilitate growth (which has been on average 2% per year for a long time), assets were bought for 25 years but easily last 40 years due to robust designs

Asset adaptability	one of the assets (articulated truck) has functional modules that can be exchanged, other assets are adaptable, but this possibility is not intentionally designed into the asset. Most assets receive a mid-life update (MLU) halfway their expected life	the trains are not designed for easy adaptability, with exception of the most recent train, which is a modular system (some older trains are based on a modular platform, but after production the design is 'fixed'). Adaptations are largely limited to the largescale overhaul and life-extension halfway the service life of the trains	adaptation of the assets is difficult, due to their location (distributed, underground) and numbers. Large assets can be adapted, but for most replacement is financially more attractive. By replacing certain assets, the grid can be adapted easily (the grid as a partial modular system)
Population agility	all assets are assigned to units, so DMO has no agility from the size of the populations (the units do), on a mission reserves are available for some vehicle types (taken from other units)	the size and variety of the fleet offers agility: the strategic reserve allows to facilitate sudden demand growth, most trains are fit for both stopping and express train services, in procurements an additional order is anticipated	there is some redundancy in the grid, for some assets there is a strategic reserve (e.g. for power transformers), new technology allows a better use of existing over capacity (e.g. by better understanding usage profiles)
Organizational agility	mainly ranges from the people (skills, knowledge, training, 'make it happen' mentality) and collaborations (internally with the user, maintainer and norm-setter, externally mainly with OEMs), strategy mainly focused on the development and adoption (in the vehicles) of new technologies	all sources of organizational agility are mentioned. Most importantly, there is the strategic fleet planning process, which forecasts the future demand and availability of trains. Internal (with NedTrain) and external (with suppliers and engineering consultants) collaborations and the knowledge of its personnel also yield agility	the organization is in transition from a stable to a volatile context. In the stable situation, agility was offered by knowledgeable experts, collaborations and strategic grid development plans. In the future, the company aims to build agility with people with new competences, flexible processes, increased insight from data and a scenario-based strategy

Agility performance

To get a better understanding of the agility performance in each of the case companies, we asked the respondents if they regarded their current agility level to be sufficient. All three companies considered their current agility sufficient (see *Table 6*), although a respondent from the NR admitted that "we are currently tight on rolling stock and actually do not have any options left to improve this". However, this is a temporal situation, as new rolling stock will be available in a few months.

Regarding the future, the three case companies realized that their agility levels were slowly declining if no additional efforts would be made. One reason mentioned across all three cases is the reduction of technical knowledge. This is even aggravated by the increasing complexity of many assets, because of the addition of electronic and software components. For Liander, an important reason for the reduction of their agility is the impact of the energy transition, which: "has triggered a trend reversal, as a result, we can no longer solve this in the old way". Finally, the NR indicated that their agility is decreasing because "we are hitting the boundaries of the system", pointing at the capacity of the railway network.

As a consequence of this reducing agility, all companies mentioned different efforts to increase their agility. DMO and the NR are considering the possibility to shorten the interval of MLUs, to accommodate more volatile user demands and to deal with obsolescence.

Additionally, "the knowledge, which used to be naturally available [at the NR], is no longer here, one needs to actively organize this". New collaborations are a means to increase agility. Liander is developing new, more agile, processes and new competences. Also, it tries to influence the development of the energy transition, in order to limit the scope of future developments and thus the need for agility. Finally, it tries to collaborate with other network operators to influence legislation, to allow a wider range of control options in the future.

Table 6 *– overview of the agility performance of the different case companies*

Agility performance	**Defence Materiel Organization (DMO)**	**Netherlands Railways (NR)**	**Liander**
Current agility	sufficient	sufficient (barely)	sufficient
Development	declining	declining	declining
Caused by	reduction of personnel due to budget cuts, more complex systems	reduction of knowledge available within the company, increasingly complex systems, higher dependency on suppliers, increasingly strict regulations, limits imposed by the infrastructure	the organization is equipped for a stable context, but the context is changing, which asks for new processes and competences. Reduction of available technical knowledge.
Current efforts to improve agility	efforts have been made to create awareness of the importance to consider the complete life cycle of the assets in Asset Management, a pilot project is running to do MLUs more often during the asset's lifetime (e.g. every 5 years)	knowledge management is receiving more attention, process optimization, data processes, more collaborations with other train operators (e.g. purchasing power, knowledge, parts and reserves), there are ideas about planning multiple smaller overhauls during the asset's lifetime, and hopes for a truly modular train in the future	development of scenarios, development of competences (e.g. working with scenarios, data analysis), changing processes to deal a wider variety of demands, pilot studies to investigate the impact of the energy transition and possible solutions, collaboration with other network operators to influence legislation

Conclusion and discussion

Agility is the ability of an organization to cope with change. Whereas in the study of agility the main focus normally lies on the organization, in this study we have focused on the assets used by an organization. As these assets are designed to last for several decades, they see many changes in their lives. Therefore, we explored agility within Asset Management organizations, based on five propositions based on our theoretical framework (see Table 7).

Our study showed that the change – the driver of agility – ranges from different backgrounds, and that all three case companies face significant changes and expect this to remain so in the future. We found that Asset Management agility ranges from three categories of agility enablers: agile assets (including asset resilience and asset adaptability), agile deployment of the assets and an agile organization. Assets were found to be agile because of their inherent asset resilience (proposition 1) rather than their design for adaptability: in contrast to proposition 2, we did not find a relation between unpredictable change – which was clearly found at DMO and the NR – and asset adaptability. Even though the assets allowed some adaptations, this potential was not intentionally designed into the assets. Proposition 3 proposed that a larger number of assets would result in a higher Asset Manage-

ment agility. This was not confirmed, as in the case of DMO the assets are allocated to the units and hence the (potential) agility is also transferred to these. In the Asset Management organization, knowledgeable and motivated people, collaborations with capable partners, future-anticipating strategies and insightful information are the main enablers of agility, which become more important in the face of unpredictable changes (proposition 4).

Table 7 *– overview of the findings related to the propositions [- means: the proposition is irrelevant to the case or the findings within the case are inconclusive]*

Proposition	DMO	NR	L	confirmed
Predictable change is reflected in the resilience of the assets.	-	yes	yes	yes
Unpredictable change is reflected in the adaptability of the assets.	no	no	-	no
The larger the number of assets available for a certain function, the larger the agility.	no	yes	-	no
The weight of organizational agility increases with the amount of unpredictable change.	yes	yes	yes	yes
When a company does not put effort into agility, its agility will reduce over time.	yes	yes	yes	yes

The three case companies are currently sufficiently agile, but see their agility level decreasing over time (proposition 5): fewer knowledgeable people, more complex systems, stricter regulations and the need to change existing processes are reasons for this. As the need for agility will remain the same or may even increase in the future, efforts are needed to increase Asset Management agility. The exploration of this concept offers an overview of the possibilities asset Managers have to do so. Additionally, it has increased our understanding of agility, by adding the perspective of agile assets to the concept of agility.

The conclusions ranging from this study are limited by the number of cases studied, more cases are needed to increase the generalizability of our findings. Additionally, based on this exploratory study a further conceptualization and operationalization of the main concepts in agile Asset Management may deepen our understanding.

This study has three main implications for practitioners. First is the need to assess the need for Asset Management agility, by studying the rate of change on the different agility drivers. Secondly, one should realize that Asset Management agility needs investments and constant attention, otherwise the organization's agility level may fall. Finally, designers and purchasing managers may be advised to look for improvements in the designed adaptability of assets, which was found to be low in most assets owned by the three case companies.

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