

PRINCIPLES FOR THE DESIGN AND DEVELOPMENT OF DASHBOARDS: LITERATURE REVIEW

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Abstract

Information overload is a recognized phenomenon related to the continuous increase of data that need to be dealt with. This overload can be managed using dashboards, which are considered one of the most useful tools in Business Intelligence, merging different concepts such as scorecards to assist stakeholders and employees to improve the performance and make the appropriate decisions. However, many software vendors do not draw the necessary level of attention to the effectiveness and usefulness of dashboards as instead they promote the ability to visualize as much data as possible for marketing purposes and they focus on the display features and maximize the visualization mechanisms. Moreover, there is a limitation in studies that investigate using dashboard in Higher Education to assist quality of decisions and actions to improve performance. Consequently, having a better understanding of using dashboard effectively within Higher Education sector can boost our comprehension of critical factors and measures and how they can be visualized appropriately that can lead to improve performance and support decisions.

Keywords: Higher Education, Dashboard, Performance Measurement, Decision Making, Balanced Scorecard, Goal Question Metrics

1 INTRODUCTION

Information overload is a recognised phenomenon related to the continuous increase of data and the corresponding need to process that information. Business Intelligence has attempted to manage overload using tools like dashboards, which enables concepts like scorecards to be merged, providing valuable information to assist stakeholders and employees to improve performance and make the most effective decisions (Yigitbasioglu and Velcu, 2012). The need for more effective communication becomes more important as the size of an organisation increases. This underlines the importance of using tools like dashboards to monitor and improve their output, as well as to improve accuracy and efficiency of the data that is available (Koopman et al., 2011).

Despite the recognised value of dashboards, many software vendors have failed to draw the necessary level of attention to the effectiveness and usefulness of dashboards, instead focusing on display features and maximising visualisation mechanisms for marketing purposes (Janes et al., 2013; Few, 2006). There is also little agreement regarding how dashboard should look like and what should do, with the majority of focusing

on considerations like its features or customisation options instead (Yigitbasioglu and Velcu, 2011). In addition, a small number of papers has studied the use of dashboard in Higher Education (HE), with particularly limited investigation of the critical factors that make using them successful in this context or the metrics to determine this success. Therefore, this paper will present the literature regarding dashboards, to provide a better understanding of their use at an organisational level.

First, general understanding of what is dashboard and how it is used within different contexts, levels, and purposes is required to support constructing an overview of using this tool. In order to specify the required metrics, a combination of two strategies, which are the Balanced Scorecard (BSC) and Goal Question Metric (GQM) is presented to improve the efficiency of using dashboard. This general understanding assist formulating the general framework that will be applied to advocate using dashboard within the context of HE, which is the case study of this research.

1.1 Dashboard

It is clear that there is a gap in understanding regarding the efficiency and scientific application of dashboards and not being simply as a work of art to attract potential customers (Few, 2006). Most vendors base such definitions on the features and technologies that their dashboard provides, instead of offering a general frame and understanding (Few, 2006). This uncertainty about what dashboards is, and keeping the definition not clarified can help vendors to keep selling their produced dashboards. The definition utilised in this study is that a dashboard is: “a visual display of the most important information needed to achieve one or more objectives; consolidated and arranged on a single screen so the information can be monitored at a glance” (Few, 2006).

Table 1. The purposes and features of dashboards (Rahman et al., 2017)

Level	Purpose	Features (Frequency of appearance)
Strategic	<p>Consistency -Improve business process -Track KPI</p> <p>Monitor -Monitor organisational performance.</p> <p>Planning - To plan the organisation future</p>	<p>Visual Features -Fit single screen -Grid overlay</p> <p>Functional Features -Graphical Presentation (Bar chart, Pie Chart, Graph, Gauge Chart) -Time horizon</p>
Tactical	<p>Consistency -To standardise the service</p> <p>Monitor -Self-monitoring the performance of management. -Understand employee's performance -Summarise information by departmental -Monitor trend over the period.</p> <p>Communication -Communicate with the operational level.</p> <p>Analysis -Improve decision making among the departments.</p>	<p>Visual Features -Fit Single Screen</p> <p>Functional Features -Graphical Presentation (Fusion, historical, bar, gauge chart) -Drill down -Scenario analysis -Drag and drop -Hide/flag component -Report -Alert mechanism -Print -icon</p>
Operational	<p>Consistency -Increase speed and consistency of analysis -For information transparency.</p> <p>Monitor -Monitor individual or group information -Monitor activity -Monitor and detect relevant information -Measure individual performance</p> <p>Communication -Provide feedback on their performance -To extract information among the team member.</p> <p>Analysis -Analyse learning analytics -Analyse user's own Information -Analyse effects</p>	<p>Visual Features - Fit a single screen</p> <p>Functional Features -Percentage indicator -Graphical presentation (bar, line, pie, network, spider, trend,gauge) -Concept map -Table -Filter -Badge -Zoom -Rating -Calendar -Alert mechanism</p>

There are substantial advantages to identifying the purpose of the dashboard based on the targeted managerial level and the features that fulfil this purpose (Rahman et al., 2017). The main different objectives of using dashboards are the ability to ensure consistency, planning, communication and monitoring (Pauwels et al., 2009; Rahman et al., 2017). Abdul Rahman et al. (2017) find out that 13 of the 23 published papers selected by the Systematic Literature Review from 2010-2017 are operational dashboards. The remaining categories are tactical dashboards (6 papers), strategic dashboards (3 papers) and a combination of operational and tactical dashboards (1 paper). The inadequacy of papers looking at strategic dashboards made it difficult to investigate the usage of dashboards at a strategic level. The main arguments for the use of dashboard and the application of such purposes within each managerial level of the organisation, along with the most salient visual and functional features, are outlined in Table.

1.1.1 Dashboards and decision making

The amount of information available to individuals and businesses is increasing at an exponential rate, with some experts claiming that the actual amount increases by 60% every year (Donhost and Anfara Jr, 2010). However, it has been argued that “a wealth of information creates a poverty of attention” (Donhost and Anfara Jr, 2010). In the era of big data, the power of data to manage our decisions indicates that fact-based decision making is increasingly important within organisations (Mandinach, 2012). Therefore, specialists able to support decision making utilise descriptive, predictive, and prescriptive analytics are increasingly in demand to provide data analysis of the vast amount of information that is available (Chen et al., 2012). As a consequence, all sectors, including education, are under increased pressure to provide evidence to support and manage the decision making process (Donhost and Anfara Jr, 2010). Access to data does not mean that it is inevitably utilised effectively, however, and being sparse in soils which cause lack of correlating them to support decision makers (Sokhn et al., 2014). In the education sector, many administrators are under increasing pressure to make decisions, leading some to experience difficulties dealing with data-driven decision making and “accruing data without analysing and using it will not help your student learn” (Donhost and Anfara Jr, 2010). Effective decision-making requires data to be integrated and interpreted, which transforms it into useful information (March and Hevner, 2007).

Dashboard is proposed as a possible support mechanism to facilitate multiple avenues of decision making, such as measuring life cycle sustainability of products and consumption levels (Traverso et al., 2012). In other words, as non-experts who are targeted by experts and scientists are part of the process of decision making, clear presentation of these information is a requirement (Traverso et al., 2012), which reinforces the importance of using a tool like dashboard to sort and utilise data effectively (Donhost and Anfara Jr, 2010). In addition, the rise of distributed decision-making has increased the importance of examining the influences of the decisions being made by operational level managers, rather than only the executives (March and Hevner, 2007).

Furthermore, the design of dashboards plays an important role because it can affect the efficacy of these tools. For example, while colours can enhance the visualisations of dashboards, overusing or misusing certain colour palettes can have a negative impact on the decision making (Bera, 2016). Using eye tracking technology, it is reported that the random use of colours in dashboards may not cause bad decisions, but may still delay the time required to make an appropriate decision (Bera, 2016).

1.1.2 Dashboard and performance measurement

It is crucial for any organisation to measure and improve its performance. The ability to numerically measure performance offers accurate data that facilitates analysis, helping to improve the quality of organisations (Arora, Kaur, 2015). As an example of this, dashboards are used in the clinical sector more effectively than electronic medical records (EMR) and computerised decision support systems (CDSS) by providing a performance measurement summary and enabling the visualisation of data (Dowding et al., 2015).

The Russian State Social University (RSSU) produced a personnel performance assessment system in an attempt to improve and optimise the quality of its faculties (Bakhtina et al., 2015). This system demonstrated that supporting and developing the motivation system is a main priority to assisting the performance assessment system (Bakhtina et al., 2015). The Key Performance Indicators (KPI) metric was also used to define the official functional tasks and the importance of these tasks (Bakhtina et al., 2015), showing that the main elements driving the success of performance measurement systems in the RSSU dashboard are design, data and display. The design component means constructing a model or framework then developing the appropriate metrics while data are the actual inputs then display graphical visualisation to express both data and design (Harbour, 2011).

1.1.3 Dashboard and balanced scorecard, same or different

In 1990, Kaplan and Norton examined many companies to find out new procedures of performance measurement. They concluded that those companies relying exclusively on financial measures which are insufficient in modern business organisations and unable to create value (Niven, 2008). As a result, they argue that achieving the required balance should involve supplementing financial analysis with other perspectives, including internal processes, employee learning and growth, and customer satisfaction (Niven, 2008). Taylor and Baines (2012) proposes Balance Scorecard (BSC) as a framework to create balanced objectives within an organisation over four different perspectives, which can be illustrated using dashboards to provide an insight into performance data, along with related trends and patterns.

BSC is connected directly to the adopted goals and plans of a company, and “can be cascaded to link all levels of an organisation to the corporate strategy” which can cause a considerable amount of work and cost, whereas dashboard provides a broader view by presenting the directions of key indicators (Taylor and Baines, 2012). An earlier study by Wyatt (2004) investigated the successful experience of St. Luke’s Episcopal Health System, which used BSC next to a visual dashboard. In this case, although BSC was able to track the requisite information, it did not provide “timely access to integrated performance data”, which was instead achieved using dashboard. Therefore, dashboard can be understood as conceptual ‘glasses’, which provide a clearer vision of the BSC elements, with BSC being seen as good ingredients fed into dashboard to display a good recipe. In other words, BSC can facilitate the data analysis process by designing an appropriate framework of metrics to enhance input and displayed data, enabling a quality of output that reflects the quality of input.

2 DATA AND VISUALISATION

The explosion in the capacity of data can overcome human cognitive capacity. Given the wealth of data available and possible inconsistency or unreliability of that data, it can be challenging to obtain the required information to support the creation of an appropriate visualisation, while also improving the quality of visualised data. In this capacity, dashboards can be a useful tool to support users in achieving their goals. Useful dashboards are characterised by two main functions: the selection of appropriate data; and the choice of the most appropriate visualisation technique (Janes et al., 2013). Fig. 1. Propose the general framework of combining two approaches BSC and GQM to generate the appropriate metrics.

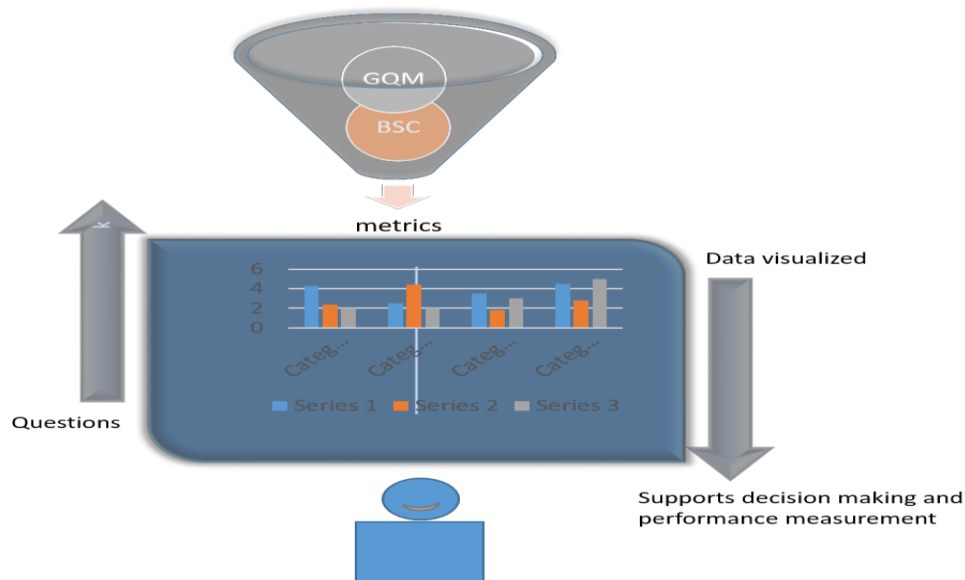


Fig. 1. General Framework for Data and Visualization to Support the End User

2.1 Selecting the Appropriate Data

Effective data requires the development of an appropriate measurement model that can define the data to be collected, based on clear reasoning and criteria (Janes et al., 2013). Measurement is “a mechanism for creating a corporate memory and an aid in answering a variety of questions...” The process of specifying

the correct measurements to use and how they should be interpreted requires suitable models, informed by appropriate goals (Basili, 1992).

Data and information quality are crucial concepts for organisations to consider. Applying analytical tools on inaccurate data will generate inaccurate information which will have a negative impact on the decision making (Haupt et al., 2015). Information quality can be specified in terms of four dimensions: accuracy, completeness, representation and objectivity (Arazy et al., 2017). There are also a number of different factors that affect the quality of data and lower reliability, such as the abundance of data, which has not been analysed properly or which has potentially not even been recognised as valuable, resulting in data that can be removed and corresponding opportunities missed (Gitzel et al., 2015).

This issue of excessive, non-selective data collection is a real problem within many organisations that can be solved by better understanding ongoing measurements to inform exploration of the collected data (Mendonca and Basili, 2000).

2.1.1 *Balanced scorecard (BSC)*

Combining objectives with formal methods is a way to support the production of comprehensive guidelines in order to develop a framework that can support the assessment of performance (Barclay and Osei-Bryson, 2010). Given the complexity of managing organisations, managers need to simultaneously view performance in multiple areas. This can be achieved using BSC, which draws the attention of users towards a smaller set of decisive measures elicited from four specific perspectives. For instance, managers can focus on criteria that reflect their mission to create specific metrics that measure factors related to the customer satisfaction perspective. For instance, managers can focus on criteria that reflect their mission to create specific metrics that measure factors related to the customer satisfaction perspective. In this scenario, the chosen perspectives might be to formulate goals for time, quality, performance and service (Kaplan and Norton, 1992). Here, the corresponding BSC definition might be to “carefully selected set of measures derived from an org’s strategy..... I see this tool as three things: measurement system, strategic management system, and communication tool” (Niven, 2008). Furthermore, there is some evidence that poor enforcement has a greater role in failure than poor strategy (Niven, 2008).

One real world example was seen at the University of Phayao, where BSC was used in conjunction with the decision support system of the school of Information and Communication Technology to track the performance over the four dimensions of BSC. This enabled selection of the most effective strategies in departmental planning (Cheowsuwan, 2016).

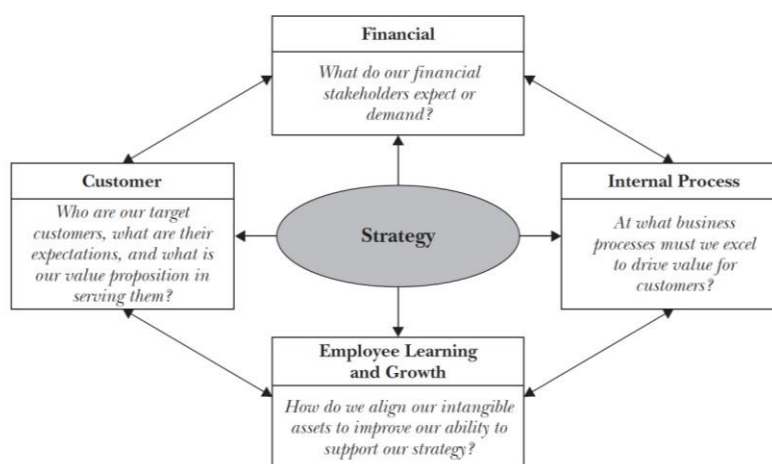


Fig. 2. The Balanced Scorecard (Niven, 2008)

2.1.2 *Goal question metric (GQM)*

Goal Question Metric (GQM) is top-down measurement tool, which functions by “defining and evaluating a set of operational goals” (Basili, 1992). A noticeable difference exists between theory and practice regarding the usability of strategy tools. Even though GQM is recognised as being useful, there is a lack of support to make the approach more practical and usable, as well as little to no information being available on how to

identify strategies (Trinkenreich et al., 2017). The required strategies for these approaches are either assigned by leaders, as a top-down approach, or by teams in a bottom-up approach, yet the relationship between IT service strategies and goals was unclear (Trinkenreich et al., 2017). This scenario also exists in HE, where IT is understood as being useful and valuable, but must be applied in accordance with suitable strategies and policies.

There are some drawbacks related to using the GQM approach, such as the possibility of creating a large number of metrics (Berander and Jonsson, 2006). Additionally, a GQM measurement framework will only focus on the defined perspectives, so may neglect other potentially valuable data (Berander and Jonsson, 2006). As measures derived from the GQM approach cannot be reused, Lavazza (2002) suggests that organisations should develop a library of goals, questions and metrics to compact measurement programs. Even reusable results need to be carefully packaged, as the future requirements of measurements are often unclear. Furthermore, the extent to which measures can be adopted or reused depends on the strategic goals of the organisation and how carefully experiences and context have been specified (Van Latum et al., 1998; Lavazza, 2000).

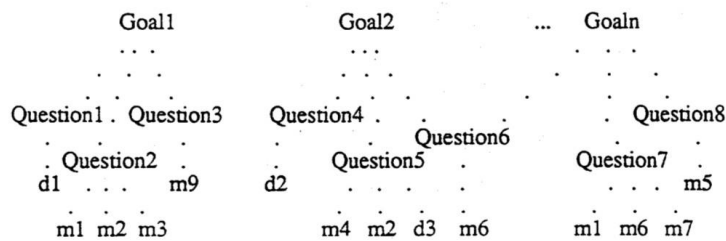


Fig. 3. Goal Question Metric (Basili, 1992)

2.1.3 BSC and GQM

Executives should define a clear strategy based on various factors, such as their vision, experience, and insight in order to ensure the alignment between their strategic and goals. This alignment can be more effectively achieved by combining two communal measurement tools, which are BSC and GQM. In this way, the organisational vision can be specified in accordance with the perspectives provided by the BSC, while the measurement is developed using the GQM approach to introduce a comprehensive measurement mechanism. Becker and Bostelman (1999) applied these integrated approaches and found that stratifying the perspectives of the BSC in conjunction with the GQM approach was highly viable. However, this success could not be approved if it occurred because of applying these combined approaches without external control from the managers. The size and scope of the study was also limited, meaning that further investigation should be undertaken to monitor the impact of this strategy over different terms of usage.

Barclay and Osei-Bryson (2010) state that cooperation between managers is essential in order to clearly identify objectives and fulfil all organisational goals. Despite the importance of this planning, these objectives are often produced based on experience, which may lead to conflict due to a lack of completeness, depending on the team members engaged. This underlines the importance and the challenge of specifying a clear method that ensures that objectives are achieved in light of the main organisation goals and that this assessed in terms of clear, suitable and unambiguous performance measures.

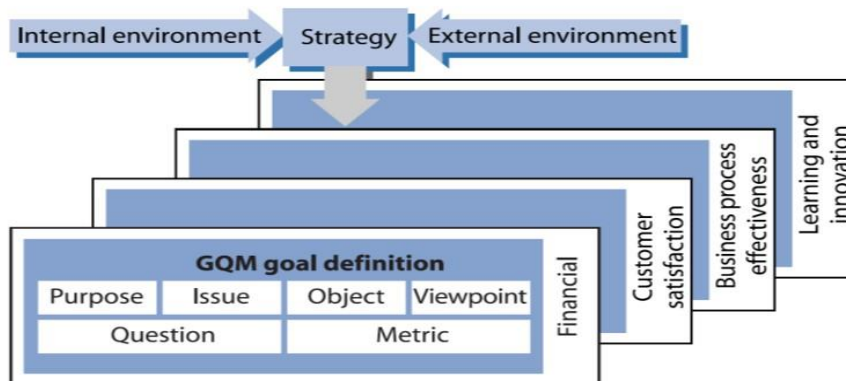


Fig. 4. Integration of BSC and GQM (Becker and Boostlman, 1999)

3 DASHBOARD IN HIGHER EDUCATION

Despite the value of dashboard in supporting decision making and performance measurement, the tool is more commonly used by conventional businesses, rather than non-profit organisations (Denwattana and Saengsai, 2016). However, there have been several attempts towards the use of dashboards in public organisations. For instance, within clinical contexts, dashboards provide more qualified feedback than traditional methods, helping decision makers to assess the quality and outcomes of the services (Dowding et al., 2015). In addition, stakeholders of public administrations can use the comprehensive overview of key issues illustrated on dashboard to inform their decision making process (Sokhn et al., 2014). Another viable use of this tool is learning dashboards, which are: “a single display that aggregates multiple visualisations of different indicators about learner(s), learning process(es) and/or learning context(s)” (Schwendimann, 2017). It is reported that there is a lack in illustrating useful information and identifying what and how information is shown accurately within the appropriate time (Schwendimann, 2017).

This research searched the following databases ACM, IEEE and google scholar by typing the keywords (“dashboard” AND “higher education”) and (“dashboard” AND “BSC” AND “GQM” AND “higher education”) in order to investigate the use of dashboard in HE. The outcomes indicate that the majority of studies in this area discuss different aspects of the application of dashboard as a tool to support students with their learning, such as for feedback, brainstorming, performance tracking, and teacher awareness in group activities. Boosalis et al. (2016) used Dataset Publishing language (DPSL) and Google’s public data explorer (GPDE) with dashboard to analyse data on student learning outcomes, in an attempt to keep them meaningful at various levels of the organisation. Furthermore, 15

A number of studies investigated the implementation of dashboard to support performance in HE. For example, Denwattana and Saengsai (2016) successfully proposed the use of TheDB (Thailand higher education dashboard) to support the nursing college of the public health ministry.

Overall, there is a lack of understanding regarding the factors influencing the successful adoption of dashboards in the HE sector, or regarding appropriate frameworks to support the production or visualisation of appropriate metrics. This limitation should be visualised and subjected to further investigation.

Table2. Themes and gaps generated from the Literature Review

Themes	Gaps
Misalignment	<ul style="list-style-type: none"> - Misalignment between measures and targets causes an obstacle to the use of dashboards (Abdul Rahman et al., 2017). - Data visualisation needs to be aligned with a purpose or intention (Echeverria et al, 2018). - There is no clear evidence to consider whether a decision method is correct and produce better outcome than another or even than no method (Letier et al, 2014). - Very few studies about the impact of dashboard on learning (Schwendimann et al, 2017). <ul style="list-style-type: none"> - Provided indicators cannot be useful if they could not be trusted by users (Schwendimann et al, 2017). - Many organisations are not aware of how or whether the measures used to support decision making are related to their goals (Trinkenreich et al, 2017). - GQM framework will focus on the defined perspectives which may neglect other potentially valuable data (Berander and Jonsson, 2006).

Themes	Gaps
Design	<ul style="list-style-type: none"> - Lack of usability testing of the design of the dashboard (Echeverria et al, 2018). - The choice of what data to be visualized might not correspond with what learners and teachers looking for, and even if the visualisation interpreted correctly, learners and teachers might fail to understand the required action to adopt their behaviour (Echeverria et al, 2018). <ul style="list-style-type: none"> - Further research in data presentation and communication using DS is recommended (Kosara and Mackinlay, 2013). - Data are meaningless without explanations, so annotations are required but have not been evaluated (Elias and Bezerianos, 2012). - Uncertainty tend to be hidden when providing information to learners about their learning in the most visualisations by applying some design techniques such as using performance categories like low, medium, high without fully addressing uncertainty (Epp and Bull, 2015). - There is a lack in presenting useful information by dashboard and understanding what appropriate information to be presented to different stakeholders and users and how it should be presented (Schwendimann et al, 2017).
Quality	<ul style="list-style-type: none"> - Poor data quality by having too much information that affects reliability analysis, lack of awareness of data value (Gitzel et al, 2015). - Systems that render relevant data automatically are important (Koopman et al, 2011). - Huge number of possible alternative solutions which are difficult to be explored manually and the lack of integrated tool to support decision analysis under uncertainty (Busari, 2017). - Using analytical tools on inaccurate data will generate inaccurate information which affect the decision making, large volume of data versus little analytical culture (Haupt et al, 2015). - The possibility of creating a large number of metrics by applying GQM (Berander and Jonsson, 2006).

4 CONCLUSION AND FUTURE WORK

In conclusion, supporting decision making process to improve performance measurement is essential task within organisations. The awareness of this importance has been raised not only by profit organisations but also, non-profit ones. This correlate with the increase of data available, which can support organisations with their decisions. However, dealing with this large amount of data and specifying the appropriate metrics is a challenging task. Consequently, dashboard is proposed as a useful tool to support decision making and performance measurement. However, the efficiency of using dashboard need to have further investigation especially within non-profit organisations such as higher education sector.

This can be achieved by looking at what should be visualized and how it is going to be visualized. This study concentrates on the first part (what should be visualized) by establishing the general framework of the successful factors of dashboard adoption. The future work of the study aiming at generating these factors by combining BSC and GQM which can enhance the input of dashboards and the alignment between goals, strategies and measures. As a result, this might have a positive impact on improving the visualized output of dashboards and decision making process to support performance measurement.

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