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IMPACT OF BUSINESS INTELLIGENCE ON COMPANY PERFORMANCE: A SYSTEM DYNAMICS APPROACH

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Abstract

Research background: Businesses struggle with operational optimisation and seek a solution by implementing Business Intelligence (BI) to boost sales. But, due to the lack of research that use actual data from real-world situations; the impetus of this research is to exploit BI parameters to enhance company performance.
Purpose: This research aims to develop a System Dynamics (SD) based model to assess whether a Japanese company which manufactures Printed Circuit Boards (PCB) should invest in BI to improve its operations based on the rate of information processing, thereby leading to increased financial performance.
Research methodology: The authors requested financial statements for three years (2019 to 2021) from the management of the PCB company, followed by validation based on subject experts' assessments. The model was developed and simulated step-by-step with consideration of the SD approach involving problem identification, model prototyping, trouble shooting and error analysis.
Results: If BI was used to process data at a rate of 40%, the endogenous factors considered in this study would increase the company's net profit and accumulated earnings by 25.77% and 48.28%, respectively.
Novelty: The research is unique in the sense that the model was developed based on inter-relationships between the variables, and the data is based on a real-life situation. Furthermore, the methodology could be applied with the necessary modifications to industries such as service, media, and education.

Keywords: Business Intelligence, accumulated earnings, net profit, production cost, number of goods produces, revenue

JEL classification: M11, M21, M29

Introduction

The benefit of any information system is subject to the extent to which it has been used in realizing the organizational objectives, yet the theory building in this direction has not been to the desired level (Trieu *et al*., 2022). Patel (2018) states that Business Intelligence (BI) by today is never a new technology instead of an integrated solution for companies, within which the business requirement is the key factor that drives technology innovation. BI is both a product and a process which companies utilise to generate useful information aiding overall performance (Nuseir *et al*., 2021). BI incorporates various processes and elements from other fields including but not limited to corporate governments, military, and intelligence driven cultures (Caseiro, Coelho, 2018). The popularity of BI in the recent decades is because of its potential to boost a company's performance and transform businesses. It can also be used to drive change in the financial services industry and bring key benefits towards financial performance in the form of increasing accumulated earnings and revenue while decreasing

production capital and Selling Gross and Administrative (SGA) expenses. BI uses Artificial Intelligence (AI) in the form of speech recognition, decision-making, visual perception, etc., and several studies have compared management outcomes when AI is used. For instance, Alekseeva (2020) carried out a comparative study of management variables versus AI adoption and found a positive association between AI, company size, capital expenditures, research and development and total investment. Trieu *et al.* (2022) employed a mixed-methods, three-phase approach to study (n = 688) and gave guidance to contextualise AI with the purpose to identify ways to enhance businesses operations.

Other researchers explored the link between BI and a firm's performance. Torres *et al.* (2018) studied this linkage using the System Dynamics (SD) technique and concluded that BI and analytics act as an enabler of organizational transformations, and thus, contribute to improved organizational outcomes. Huang *et al.* (2022) studied the impact of BI on the financial performance of start-ups and concluded that BI has an ancillary role on financial performance. Yiu *et al.* (2021) found BI to directly impact profitability and reduce risk in profit returns. Additionally, studies of Mikalef and Gupta (2021) provided evidence that AI adoption enhances organisational creativity and performance. Lateef and Keikhosrokiani (2022) have found that knowledge management, technology orientation, market intelligence, and entrepreneurial orientation were the critical factors which affected the performance of Small and Medium Enterprises (SMEs). Furthermore, researchers in developing countries such as China observed that BI has a significant positive impact on firm performance, that is, it enables organisations to redesign their routines to generate competitive advantages and improve performance (Chen, Lin, 2021). This notion is consistent with studies that found a connection between BI and improved company performance, but also urged the management to take time-lag effects into account to avoid undesirable results (Božič, Dimovski, 2019). Studies in the field of BI have also helped to advance its theoretical understanding by demonstrating the advantages of BI on overall company performance rather than the current anecdotal evidence (Alsaad *et al.*, 2022). While many of these studies have demonstrated the relationships between BI and parameters of interest, there are not many that use actual data from real-world situations to offer quantifiable evidence of the use of BI in improving company performance. So, the main motivation in this research is the desire to exploit the capabilities of the SD approach to test the impact of BI on parameters which define a company's performance. So, a company in Japan which manufactures Printed Circuit Boards (PCB) and is desirous to implement BI has been considered as a case and the research has been undertaken. This research aims to develop a SD based model to assess whether the Japanese company manufacturing PCBs should invest

in BI to improve its operations based on the rate of information processing, thereby leading to improved financial performance.

1. Literature Review

This paper revolves mainly around how BI influences the financial performance of a company. Production capital, accumulated earnings and overall revenue being key indicators of the financial performance of a company, the literature of BI in relation to these parameters have been reviewed to identify the research gap.

1.1. Business Intelligence

Frankenfield (2022) defines BI as a technical and procedural infrastructure that parses data and produces reports that help managers in making better business decisions. Wanda and Stian (2015) claim that BI is generally viewed as an umbrella term which consists of various processes, technologies, and activities to collect, analyse, store, and spread information to achieve improved business decision-making.

The use of digital technologies generates large amounts of data that is used by BI to make decisions and improve management within a company (Basile *et al.*, 2023). Furthermore, BI can be used by companies in today's very competitive world to gain a competitive advantage over another company (Jakhar, Krishna, 2020). In order to achieve faster and flawless business decisions, companies can adopt BI which can assist them in mechanizing the tasks of analysis, decision making, strategy formulation and forecasting (Yang *et al.*, 2022).

Analysis has shown that an investment in BI by Michigan State University generated annual savings of $34,434 and a 55% return by eliminating manual data analysis, therewith allowing staff to concentrate on critical activities and hence increasing revenue (Sestino, De Mauro, 2022). BI and analytics can be used by organisations to transform business through a holistic integration process (Ramakrishnan *et al.*, 2020). Furthermore, BI has a positive impact on the speed of internationalization with organisational agility mediating this relationship (Cheng *et al.*, 2020). Other studies reveal that BI has a positive impact on small and medium enterprises (Caseiro, Coelho, 2018). In contrast, authors differ in their opinions on BI and its impact on the performance of a company. According to Richards *et al.* (2019), organisations can successfully use BI and analytics if they have the ability to adjust to newer technology through sound business planning and strategic implementation. This paper utilises SD based modelling and simulation to study the impact of BI on a company's performance.

1.2. Accumulated Earnings

Accumulated earnings (also called- retained earnings, earned surplus, or retained capital) is an accounting term used widely by shareholders and corporations. Accumulated earnings are fundamental in funding and allocating resources. They significantly impact a company's capacity to pay dividends to stakeholders (Kenton, 2021). Accumulated earnings play an important role in firm performance in terms of competitiveness, profitability, firm size etc. Accumulated earnings along with dividends, debt, free cash flow, and net working capital affect the investment decisions of manufacturing companies (Attarie *et al*., 2018). Khazaei (2021) stated that one of the most important indicators of a company's performance is accounting profit and effective factors analysis. This would then help analysts analyse the parameters that influence profit, company performance, and other important aspects relating to its performance which can be used to make business decisions and allocate resources.

Accumulated earning is the total profit left with the company after it has paid its dividends and is calculated at the beginning of the fiscal term. It is also used as a metric of company's capacity to pay off expenses and taxes. It is important to note that accumulated earning is not the cash left over in a company after paying dividends, rather, it is indicator of what the company did with its profits; it is the amount of profit that a company has re-invested in itself since its inception (Tracy, 2020).

1.3. Net Profit

Net profit or net earnings indicates the amount of revenue that is left after subtracting all expenses and income within a particular time period (Kagan, 2020). Net income is usually found at the end of the income statement and as a result is also called an organisation's "bottom line" number (Kagan, 2020). Net income is a true indicator of a company's financial performance and can be used as a decision support tool by shareholders to determine the company's profitability (Kenton, 2021).

Studies have found net profit margin have a positive and significant effect on a company's share value in the manufacturing goods sector (Sihombing, Hutagalung, 2020). While the current and quick ratios have little bearing on return on assets, the net profit margin does, and as a result, is crucial to understanding a company's financial standing (Tumanggor, 2020). Additionally, researchers observed that net profit margin combined with positive cash flow had a notable impact on the financial management of a company (Margie, Habibah, 2022). Net profit is an indicator of the fundamental profitability of an organisation (Jayathilaka, 2020).

1.4. Production Cost

Production cost is an economic metric used to evaluate the financial performance of production in an organisation (Ciaian *et al*., 2013). Cost of production is the price that all firms must incur while providing a service or manufacturing a product. These costs include a variety of expenses including raw materials, labour costs, transportation costs etc. Production costs incur both direct costs (E.g., cost of raw materials, salary of workers etc.) and indirect costs (E.g., rent and utility expenses). Hence, production costs can be calculated by adding the direct and overhead costs together (Hayes, 2023).

Forecasting production costs can be invaluable for a company as it can help with effective production scheduling, inventory management, reduction of costs, optimized transport logistics and higher customer satisfaction (Ostdick, 2018). Developing the cost of production budgets can help keep the planning organized and focused and assist with the key information in making management decisions on cropping practices, input usage, and risk management (Walters, McClure, 2021). Suzan and Nabilah (2020) observed that the cost of production alters a company's net profit, since high production costs directly affect the sales and profit margins of an organisation. Furthermore, researchers concluded that the cost of production impacts the profit and that the probability of lowered cost of production had a positive impact on net profit whereas, sales did not have any such effect, making production cost a valuable factor in analysing financial performance (Suzan, Nabilah, 2020).

1.5. Revenue

Hayes (2023) states that revenue is the amount of money generated through regular business functions of a company and can be calculated by multiplying the number of goods sold with the average sales price. Revenue can also be viewed as an inflow of assets that are obtained from selling goods and providing services (Scott, 2003). It is usually received in the form of cash but sometimes can be obtained in the form of receivables which can be converted to cash later. Revenue can include the money collected from taxes, fees, sales of goods and government grants (Hayes, 2023). According to Campbell (2021), calculating revenue data precisely can serve a plethora of benefits such as forecasting operating expenses, analysing market trends, determining potential growth strategies, and updating the pricing strategy.

2. Conceptual framework

2.1. Research methodology

This study employs Forrester's (1961) SD modelling approach and is exploratory and empirical in nature. Several researchers (Coyle, 1977; Jessen, 1990; Maghsoudi, Nezafati, 2023) have used this method to simulate models. Both in terms of methodology and purpose, this design is pragmatic. The authors requested the financial statements for a total of three years (2019 to 2021) from the management of a PCB company in Japan. The business operates in a conventional manner and wants to implement BI to enhance their financial performance. The management was assured that the information would only be used for research and that their anonymity would be protected. This was followed by a thorough literature review to identify relevant endogenous factors, which was then presented to a group of five subject experts for validation. This step is crucial because it ensures that there are multiple perspectives in addition to those found in the literature (Maghsoudi, Nezafati, 2023). Later, the factors were deduced based on their assessment and the model was developed. The step-by-step approach to solve a problem using SD is as follows: (1) Identification of the problem statement, input, and output parameters. (2) Building a basic model and prototyping. (3) Simulation and validation of the model. (4) Error analysis, trouble shooting and enhancing.

2.2. The System Dynamics Model

This research is based on a PCB manufacturing firm located in Japan whose annual revenue is 6.5 million dollars. The cost of manufacturing one PCB board is $10. This company is a major market player and needs to keep up with competition and is in the process of developing a fully-fledged BI. In this research, we examine the viability of BI implementation and estimate the gestation period. The initial investment is considered to be about one-sixth of the total revenue. Furthermore, simulation is carried out to measure parameters of interest-change when the rate of data production is increased in steps of ten. The USD has been considered as the unit for convenience and the stock and flow diagram (Figure 1) shows the relationship between the various parameters of interest in the study.

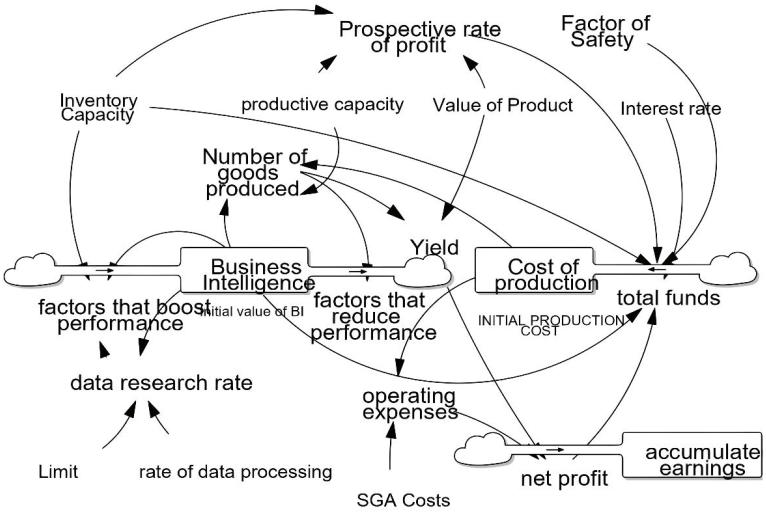


Figure 1. The SD model

Source: own elaboration.

2.3. Variables of Study

Net profit, accumulated earnings, cost of production, revenue and *number of goods produced* have been considered as the variables of interest for this research. While BI implementation can be modelled in several ways, this research considers the rate of data processing through BI as the exogenous variable and all the rest as the endogenous variables. The PCB industry under consideration has a revenue of 6.5 million USD, out of which, the base run was conducted for an investment of 1 million USD in BI. This value was later simulated for an increase of 40% in steps of 10%. The influence of the rate of data processing in steps of 10% on the parameters of interest have been considered for the time series analysis.

Research has shown that R&D, competition, increase in productivity and the concentration of mean work increase the performance of BI whereas, factors such as risk of jobs, lack of skills, data bias and cost of adoption decrease the performance of BI (Kumari *et al.*, 2021). This causation has been depicted in Figure 2 and provides a general overview of variables that directly influence business performance.

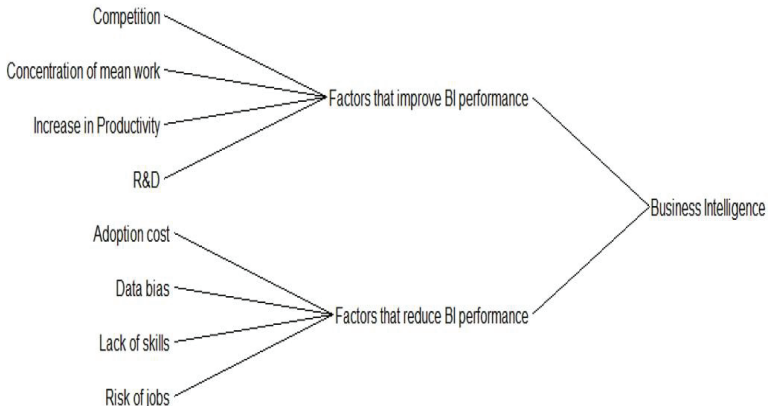


Figure 2. The factors that impact BI

Source: own elaboration.

3. Results and discussion

BI provides a good understanding of a company's operations and major challenges and is an important driver of a positive change with boost to the company's performance in a short period of time when compared to other methods. This result is in tune with the findings of other research studies in many different contexts of the use of BI (Chen, Lin, 2021). There is evidence that BI has promoted the transformation of information techniques to optimize business decisions and operations (Chen, Lin, 2021). A group of researchers have associated a positive correlation between BI and a company's financial/non-financial performance (Huang *et al*., 2022; Jones, 2018; Lateef, Keikhosrokiani, 2022; Mikalef, Gupta, 2021; Yiu *et al*., 2021). The impact of BI on the exogenous variables of interest have been discussed in the following sections.

3.1. Impact of Business Intelligence on net-profit

The simulation results indicate that BI has an impact on the net profit (Figure 3). This revelation is in alignment with other research studies in many different contexts of business (e.g., Mikalef, Gupta, 2021; Yiu *et al*., 2021). On introducing BI to the overall system, it is observed that net profits increase from $1,600/day to $1,850/day or a 15.625% increase from initial value when BI is increased to 40%.

On the other hand, increasing BI from 10% to 30% in steps of 10, see the graph (Figure 3) produces a non-linear pattern. While it is predicted that this can increase the net profit to $2,200/day or a 37.5% increase from initial value, the company must equip itself in advance to deal with the non-linear behaviour of other operational costs that may rise. In both alternatives, the net profit increases significantly which implies that BI has a positive impact on net profits. This result is consistent with the findings of Maghsoudi and Nezafati (2023), who noted that the advantages of BI lies in its ability to give organisations insightful data that can boost their competitiveness, and thereby its profitability.

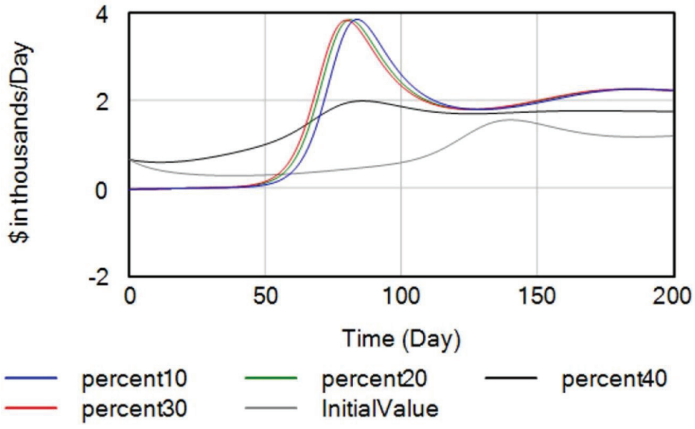


Figure 3. Impact of BI on the net profit

Source: own elaboration.

3.2. Impact of Business Intelligence on accumulated earnings

BI has a significant impact on *accumulated earnings* and this revelation is in line with the findings of researchers in other contexts of business (Huang *et al.*, 2022; Seddigh *et al.*, 2022). Accumulated earnings increase by 37%, from $1,750,000 to $2,400,000 when BI is added to the system. It is observed that accumulated earnings increase drastically with the introduction of BI into the system (Figure 4). It is seen that when the impact of BI is increased by 40%, the time taken for improvement starts from the beginning in contrast to a 10%, 20% and 30% increase where the improvement can be observed only after 50 days. Additionally, the increase in accumulated earnings with a 40% increase in BI is steady, which will allow the company enough time to plan and equip itself to counter an increase in demand.

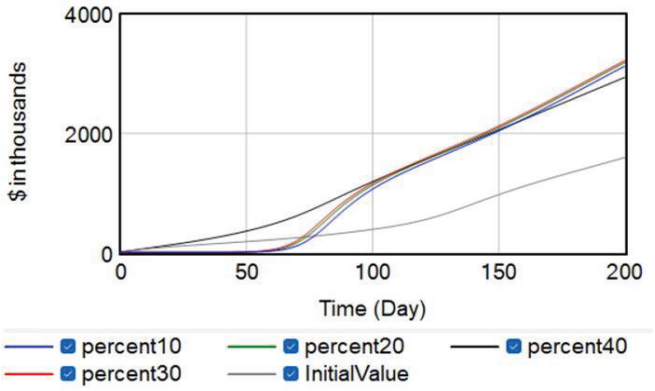


Figure 4. Impact of BI on accumulated earnings

Source: own elaboration.

3.3. Impact of Business Intelligence on cost of production

The cost of production holds the key in the success of any manufacturing company. The impact of BI on the *cost of production* is significant as depicted through the modelling and simulation in this research. Similar results have been obtained by other researchers in many other business contexts (Alekseeva *et al.*, 2020; Sestino, De Mauro, 2022). It can be observed that when BI is introduced, the time taken to reach the peak reduces from 100 days at the initial value to 75 days with a 40% increase in BI. This increase in production cost arises due to an increase in demand. This gives an indication to the managers of the company that they should

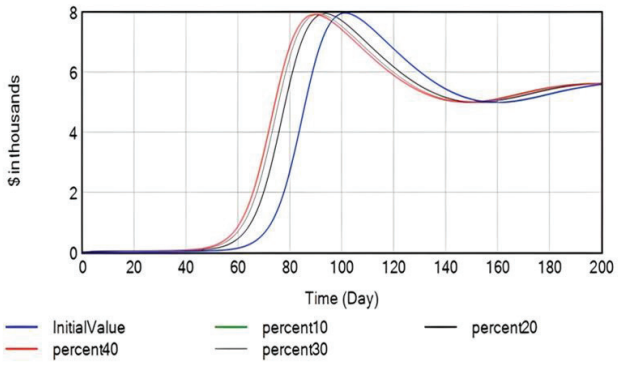


Figure 5. Impact of BI on the cost of production

Source: own elaboration.

be prepared well in advance to deal with an increase in the cost of production. Additionally, following the initial rise, the cost of production lowers by around 37.5% which is concurrent with the findings of other studies (Maghsoudi, Nezafati, 2023). This is attributed to higher operational efficiency in the organisation.

3.4. Impact of Business Intelligence on yield (Revenue)

The simulation indicates that BI has a significant impact on *revenue* generated in business (see Figure 6) and this revelation is in corroboration with some of the earlier research studies (Lu *et al.*, 2014; Shao *et al.*, 2022). It can be observed that when BI is increased by 40%, there will be a reduction in total time to reach the peak from 90 days to 75 days. This indicates that there is a reduction in total time to reach peak revenue by 20%. Thus, it is evident that increasing the rate of BI would be very effective in maximizing revenue.

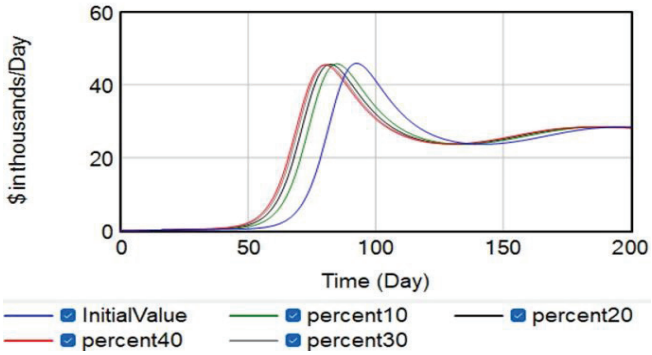


Figure 6. Impact of BI on the revenue

Source: own elaboration.

3.5. Impact of Business Intelligence on number of goods produced

The impact of BI on the volume of production has been studied by earlier researchers and a positive correlation has been established between the two in various business contexts (Duarte *et al.*, 2022; Seddigh *et al.*, 2022). It can be observed below (Figure 7) that the number of goods produced can be expected to increase with an increase in the use of BI. The time taken to reach the peak value reduces from 90 days to 75 days which means that there is a reduction in total time to reach the peak by 20%. The increase in BI from 10% to 40% in steps of 10 is nonlinear. As a result, the use of BI in the company enables the managers to anticipate an

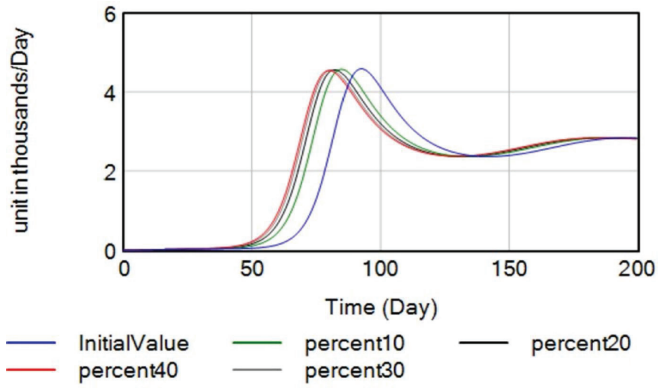


Figure 7. Impact of BI on the number of goods produced

Source: own elaboration.

increase in the overall number of goods produced, but they should also come up with plans to deal with the rise in production costs and other operating costs, which are expected to rise in a non-linear pattern.

Conclusions

This research has proposed a novel integrative modelling approach for the impact of BI on the performance of a PCB manufacturing company, and it provides an insight into the mutual and ever propagating interactions taking place within the system. Through the proposed model, it has been observed that the adoption of BI had a positive impact on *net profit, accumulated earnings, cost of production, revenue* and *number of goods produced*. Thus, this model could be useful to management consultants as a decision and forecast support tool.

Modelling and simulation have indicated that for an increase in the rate of data processing from 10% to 40%, the net profit and accumulated earnings of the PCB manufacturing company increase by 25.77% and 48.28% respectively. BI also had a positive and significant influence on revenue and the number of goods produced. Revenue increased by 7.30% and the number of goods produced by 9.37% when the rate of data processing was increased. On the other hand, cost of production had a positive impact on the adoption of BI where its value reduced to half of its initial value of 0.01 million dollars. Furthermore, increasing the rate of data processing by 40% decreases the cost of production by 25%. However, this dip in profit is negligible when compared to the significant rise in revenue on the adoption of BI. While these figures cannot be generalised completely to a manufacturing company as there

could be some extraneous factors that may cause a confounded relationship, the model can be used by future researchers for simulating the various parameters to increase the overall performance of a company. Additionally, because this research methodology and design was based on real-world data, it could be replicated and applied with the necessary modifications to industries other than manufacturing, such as service, media, and education. In this era of the IT revolution where computing and analytics have invaded almost all walks of life, BI is a very promising management tool which has been tried very successfully in both the manufacturing and service-based organizations. As a limitation, this study did not analyse the success rate of BI; however, this is a domain where additional research would add significant empirical evidence to the body of knowledge.

Appendix A

1. AE = INTEG (NP, 20)
   Units: $ (in thousands)
2. BI = INTEG (FBP – FRP, Initial value of BI)
   Units: $ (in thousands)
3. CP = INTEG (TF, IPC)
   Units: $ (in thousands)
4. DRR = IF THEN ELSE (BI < Limit, 0, RDP)
   Units: 1/Year
5. FS = 0.5
   Units: Dmnl
6. FBP = DRR × BI × (1 – BI/IC)
   Units: unit/Year
7. FRP = NGP
   Units: unit/Year
8. FINAL TIME = 200
   Units: Day
9. IPC = 0.01
   Units: $ (in thousands)
10. INITIAL TIME = 0
    Units: Day

11. Initial value of BI = 1
    Units: $ (in thousands)
12. IR = 0.2
    Units: 1/Year
13. IC = 10
    Units: unit
14. Limit = 0.05
    Units: unit
15. NP = YL – OE
    Units: $ (in thousands)/Day
16. NGP = PC × BI × CP
    Units: unit (in thousands)/Day
17. OE = SGAC × CP
    Units: $ (in thousands)/Day
18. PC = 13
    Units: unit/(unit × $ × Year)
19. PRP = VP × PC × IC
    Units: 1/Day
20. RDP = 0.1
    Units: 1/Year
21. SAVEPER = TIME STEP
    Units: Day
22. SGAC = 0.1
    Units: 1/Day
23. TIME STEP = 0.05
    Units: Day
24. TF = NP × (IR/PRP) × (BI/(IC × FS) – 1)
    Units: $/Day
25. VP = 50
    Units: $/unit
26. REV = VP × NGP
    Units: $ (in thousands)/Day
27. Annual revenue = 65,000,000
    Units: $

28. Cost of Manufacturing: 10
    Units: $/unit
29. Initial Investment: 1,000,000
    Units: $
30. Incremental increase in rate of data processing = 10%
    Units: Unitless
31. Initial number of production units: 21,000
    Units: No's

Abbreviations

1. AE = Accumulated Earnings
2. BI = Business Intelligence
3. CP = Cost of Production
4. DRR = Data Research Rate
5. FBP = Factors that Boost Performance
6. FRP = Factors that Reduce Performance
7. FS = Factor of Safety
8. IC = Inventory Capacity
9. IPC = Initial Production Cost
10. IR = Interest Rate
11. NGP = Number of Goods Produced
12. NP = Net Profit
13. OE = Operating Expenses
14. PC = Productive Capacity
15. PCB = Printed Circuit Board
16. PRP = Prospective Rate of Profit
17. RDP = Rate of Data Processing
18. REV = Revenue
19. SD = System Dynamics
20. SGAC = Selling, General and Administrative Costs
21. TF = Total Funds
22. VP = Value of Product

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Data availability

The authors have shared all simulated data in Appendix A.

Conflict of interests

The authors declare no conflict of interests

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