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Modelling manufacturing employees' performance based on a system dynamics approach

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*Manufacturing, Cranfield University, Cranfield, MK43 0AL, UK** Corresponding author. Tel.: +44 (0) 1234 758344. E-mail address: k.salonitis@cranfield.ac.uk**Abstract**

Employee performance is a key factor for the success of any modern organization. Employees are an asset that cannot be imitated by the competition, and therefore should be considered the most valuable resource. Unfortunately, they are also the hardest to control. Previous studies in manufacturing organizations have proven this. Performance improvement initiatives with a wide range of approaches are used in an attempt to improve employee performance. Motivation or organizational commitment are some examples of such programmes. However, the clear majority do not focus on the bigger picture. A conceptual model through system dynamics of the factors that affect employee performance and the different improvement initiatives is presented in this paper.

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Keywords: continuous improvement; employee performance; system dynamics**1. Introduction**

Employee performance is a key factor in the success of any organisation. In the service sector, it is the most important factor given the direct contact between employees and the customers. In manufacturing, employees are still relevant in the production processes, but more importantly are the initiators and drivers of changes and improvements in the design, planning, supervision and evaluation.

As an asset that cannot be imitated by the competition, companies put great emphasis into achieving high levels of employee performance to gain a resource advantage [1]. To do so, companies employ improvement initiatives. These initiatives aim to address waste in manufacturing processes and business design, reducing the non-value adding operation and increasing performance could improve profits. A key aspect of these programs are employee performance improvement plans. However, the necessary investments and results are often unexpected.

Due to the number of factors affecting employee performance and the human aspect in these initiatives, they

involve multiple challenges that have to be identified and considered. These challenges are both sourced to the internal and external environment of the organization. In the literature to date, research is focused on measuring a specific aspect of it – such as motivation or training for example – and not addressing the bigger picture. Further to this, there is a high level of uncertainty when it comes to human behavior, that complicates further any attempt to predict the outcome of such initiatives.

In the present paper, a model is proposed for the estimating the results and outcome of improvement initiatives on the employee performance. The focus is also on the analysis of the sustainability of the initiatives, as employees are a dynamic resource and their performance may decrease over time. For this reason, the factors that affect the employee performance are identified and collected, the relationships between the factors and the causal loops are mapped. Based on that, a system dynamics model of the employee performance is developed. For the testing of the developed model, a manufacturing company was used as case study in the UK.

2. Factors that affect the employee performance

Literature was reviewed to identify the different factors that can affect employee performance. Employee performance can be considered as a combination of both quality and quantity of the work done. This allows for a wider pool of factors to be identified, in an effort to make the model as comprehensive as possible. Previous work on employee performance has focused on organization factors or individual factors, usually focusing in only one level of employee performance. This disregards the effect other factors have on the ones being examined, while studies show that employee performance may be a holistic issue [2].

The performance factors can be categorized in the following two categories: main and secondary factors. This classification is based on their origins and their effects on the employee performance.

2.1. Main factors

The main factors are the those that have a direct and clear impact on employee performance. They have more connexions with other factors or initiatives than the secondary ones. Usually, the end goal of the improvement initiatives is only affecting one of these factors. The literature review lead to the following three main factors:

- Employee well-being – for the multitude of factors affecting it and for being the key factor to control the performance decrease.
- Motivation – for the multitude of factors and initiatives affecting it and for its impact on other factors all across the model.
- Attention to detail – for its importance in the quality control systems, a common feature to most companies and the only source of oscillations in the final quality levels on the experiments.

Employee well-being (EWB) is a complex concept that refers to more than just health or satisfaction; it comprehends both the physical and mental health of the employees. It is often identified as stress, but stress should be seen just as one of the multiple dimensions that it contains [3].

Studies show direct connections between EWB and productivity. Failing to include health-related factors when optimizing systems may lead to underestimating the running costs [4]. Particularly, the minimum costs may increase by up to 32% of the costs originally estimated.

Van Laar et al. [5] developed a scale to assess EWB by using multiple items categorized in 6 factors: career satisfaction, general well-being, home-work interface, stress, control at work and working conditions. Both the direct connection with performance and the number of factors related to EWB make it a main factor.

Motivation affects employee performance. It can be considered as a form of employee engagement, which is commonly defined as the factor that makes employees go beyond their duty. Work environment, leadership, teams, career development, rewards, organisational policies and workplace well-being have all been associated to employee engagement [1].

Attention to detail: Quality control systems are common across the manufacturing industry. The equivalent in the service industry would be performance appraisals (in terms of quality of services provided or customer satisfaction). The common feature for them are periodical reviews and adjustments of the work procedures.

However, the quality often opposes the schedule pressure. This creates a back and forth effect on the attention to detail, either increasing it to meet the desired quality or decreasing it to meet the schedule targets. This creates a balancing loop, which will create oscillations on the performance levels over time (with a period that depends on the quality system frequency).

2.2. Secondary factors

Secondary factors are defined as the ones that might have a direct effect on employee performance, but most of the time affect other factors (mostly the main ones). They are the middle point between the improvement initiatives and the main factors/performance changes.

They could be omitted in a high-level model, but given the complexity of the relationships between factors and performance, they are necessary to show the information flow from initiatives to results. The secondary factors include the following.

Adaptability is the speed with which the employees reach their usual performance level and the ability to gain advantages after major organisational or departmental changes. These changes are produced by the organisation's attempts to improve their operations and processes, and therefore may bring performance growths if the employees adapt to them appropriately.

Learning is defined as the ability to develop a new skill that could help the employees in their work, but only the learning associated to specific training or courses will be considered. This is because the focus is the impact of improvement initiatives, and the natural changes over time (like experience) are not being considered. Apart from training, other factors like employee motivation or task complexity should also be considered when evaluating the learning ratio of the employees [6].

Job Satisfaction can be linked to changes in performance [7], as it describes the employees' views on their work and work environment. Its effect can be modelled through motivation, and it has a wide range of predecessors, whose links will be described in their subsections

Organisational commitment are the positive sentiments and loyalty the employees can have towards their organisation. Position, working conditions, personal development and working arrangements are some of the factors that can affect organisational commitment. However, the employees' personality and career plans can greatly modify these factors and how organisational commitment affects performance [8]. Therefore, organisational commitment should be modelled using the data collected from the employees in the case studies.

Competition: One of the factors that affects organisational commitment are the offers from other companies of the same sector to the employees [1]. This issue is more frequent the

higher the required qualifications and rewards associated to the position are. Nevertheless, it should always be considered by asking the employees about it during the data gathering.

Flexible working arrangements are those that allow employees to change their working hours or location during work. Although they could be considered an initiative, they are considered a factor instead for one specific property – they do not require resources to be used. Flexible working arrangements are an inexpensive resource that organisations can use to improve the job satisfaction and organisational commitment of their employees [8]. There are two types of flexible working arrangement: formal and informal

Formal flexible working arrangements are on the company policy. The most common system is allowing employees to choose their starting and finishing work hours within a range as long as the total working hours remain the same. On the other hand, informal flexible working arrangements are those that are agreed on by employees and their direct supervisor individually. In most cases, only employees that have previously displayed positive behaviours and performance can make use of them, as they usually require managers to make minor changes to schedules and project plans. They are frequently situational arrangements, a temporary solution used to make it easier for the employee to deal with unexpected issues. However, the exclusivity of these arrangements may negatively impact other employees' views on the equal treatment. Formal arrangements have a greater impact in job satisfaction than in organisational commitment since they have become more common and are no longer considered as something from “special companies”.

On the other hand, informal arrangements directly impact the motivation of the employees, since they create a feeling of “needing to give back”. This feeling is towards the managers that allow the arrangements rather than the company itself, therefore the impact on motivation and not on organisational

commitment. Finally, the negative views of the employees on equal treatment (from perceived unfair informal arrangements) damage their view of the company and consequently the organisational commitment [8].

External Environment: As mentioned before, some issues unrelated to the organisations can affect the employees' motivation or well-being, for example their families or personal life [3]. However, given the complexity of these issues and the necessity of gathering detailed personal data about each employee, they will not be included in the model.

Absenteeism is usually considered as a fixed percentage of the employees. Its effect can be quantified as a fixed value modified by the possible effects of motivation and EWB on it.

3. Initiatives for employee performance improvements

The improvement initiatives are the start of any performance change. They require resources to function and represent where the company's focus on improving is. Such resources may be related to employee's time or/and capital investment. Their focus is usually one of the main factors (i.e. reward system tries to increase motivation) or a secondary factor with a clear and direct impact on one of the main factor/performance. Detailed information of the initiatives needs to be collected as they vary from one company to another. A thorough literature review of relevant publications has resulted in the following list of potential initiatives.

Employee time related initiatives:

- **Training:** As in learning, this initiative is considered as only the training received by experienced employees to obtain new capabilities and skills.
- **Change Agent:** Defined as the time expended by managers in finding and forming employees that can be an example and guide for their peers during organisational changes, increasing their adaptability.
- **Schedule Pressure:** Initiative in which the extra time from

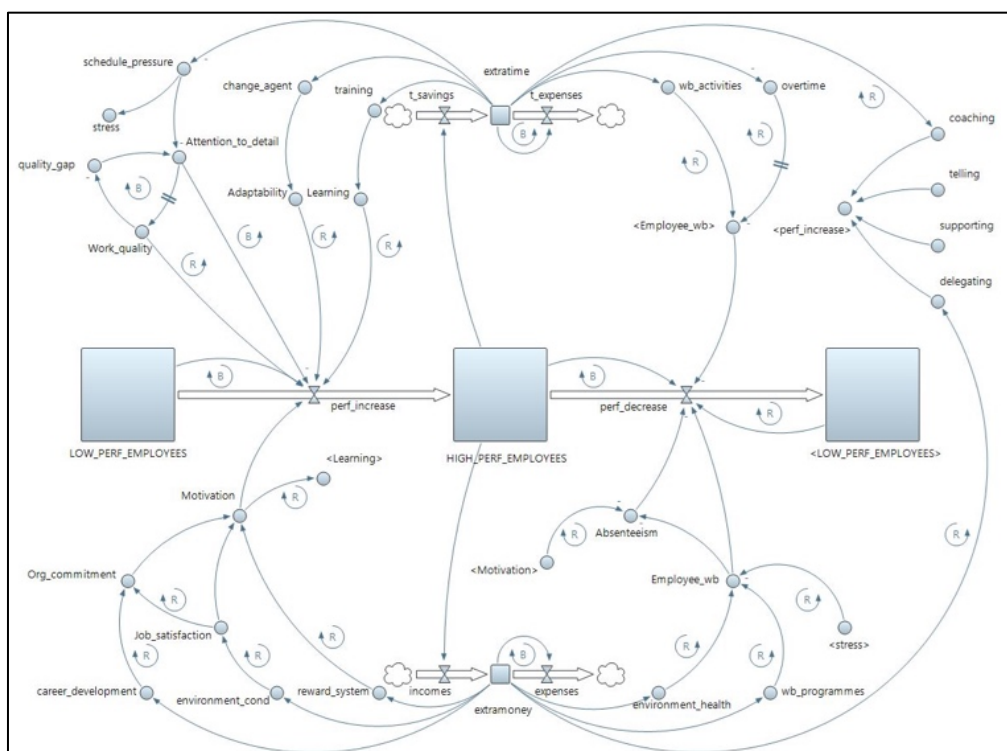


Fig. 1. SD model overview.

some employees is used to decrease the pressure of other teams with close deadlines. Used to avoid decreasing the attention to detail (and having higher quality gaps).

- Overtime: Similar to schedule pressure, focusing to help other teams that require their employees to work overtime.
- Well-being Activities: Activities organised using the employees working hours to improve their physical and mental health.

Capital investment related initiatives:

- Reward System: Extra pays and monetary rewards given to employees who show high levels of performance or solve complex issues, generating extra value.
- Environmental Conditions: Investments in improving the workplace conditions, in particular things that can affect employee satisfaction like the company facilities.
- Career Development: Investments in forming or promoting employees, creating a path they can follow to develop their professional careers.
- Environmental Health: Investments in improving the workplace that can affect the employees' health, like safety or illness prevention measures
- Well-being Programmes: Activities offered to the employees to help them maintain an appropriate lifestyle and well-being, like sponsored gym fees or healthier meal options in the canteen.

4. Leadership

In a recent study, the importance of leadership in the introduction of lean manufacturing was investigated [9]. It was shown that leadership style is critical in the employees' performance. One of the most reliable leadership models is the one presented by Hersey and Blanchard [10]. The so called situational leadership divides leadership into four styles that can be used independently and changed as necessary: telling, coaching, supporting and delegating.

Telling is the simplest of the styles, and consist on the managers giving precise instructions and orders about what to do to. Coaching consists on managers telling employees what to do while they also explain and teach them how to do their tasks. It is this style that helps the employees learn and gain confidence the most, but also the one that requires more time from the managers.

Supporting can only be used when the employees can work independently. Assignments are provided and the managers make themselves available to the employees for support when needed. Most of the time the help required is related to resources and organisation rather than task direction. Delegating completely gives the task responsibilities to the employees, and managers only review the results. However, it requires highly qualified employees to be used, which frequently means extra expenses in salaries.

5. Modelling

Nowadays there are a number of modelling options when simulating a manufacturing organization. These can be classified into three main streams, the agent based modelling, the discrete event simulation and the system dynamics (SD). Out of the three options, SD is the most promising in building a model that could predict the impact of employee performance initiatives.

In the past, SD has been used extensively in the modelling of strategy and policy changes. In the manufacturing domain, a number of studies have been presented using SD for modelling initiatives such as for example the introduction of 5S policy [11], and assessing the lean maturity [12].

SD is chosen as the simulation technique for reaching a better understanding of these initiatives and all the relationships between factors affecting employee performance. Sterman [13] remarks the importance of two steps before starting the development of a SD model. The first is setting clear boundaries for the project scope. The model developed considers only changes to performance due to the initiatives and not all the possible changes like experience over time or recruiting new employees/managers.

The second step is to set dynamic hypotheses, assumptions to explain the dynamics of causal loops, feedbacks and stocks and flows of the model. These assumptions are a temporary solution to start the modelling process, and as such can be revised or eliminated further into the process:

- Employee performance is a combination of quality and quantity of work
- High performing employees generate resources (time and/or money) that the company can reinvest in other initiatives or save
- The effect of the initiatives and factors is percentage based

The last hypothesis is very important. Given the human variability, there is not an accurate way of modelling the employees' response to each initiative, as each individual may respond differently. To gather information about the effects, data collection based on a survey for each organization is needed.

5.1. Model overview

A high-level overview of the model is presented in fig. 1. A number of parameters have been eliminated for clarity purposes, as this is intended to show the causal loops between variables and stocks and flows.

The core of the model is the stock and flows of employees between different levels of performance (in the middle). There are smaller stocks and flows at the top and bottom representing the resources (time at the top, money at the bottom), from which the different initiatives start.

The following subsections will go into detail on each part of the model. Given the complexity and number of variables and parameters, the model was divided into sub models using "shadows", a SD tool that allows the user to create copies of the variables to divide the models into smaller, easier to understand parts.

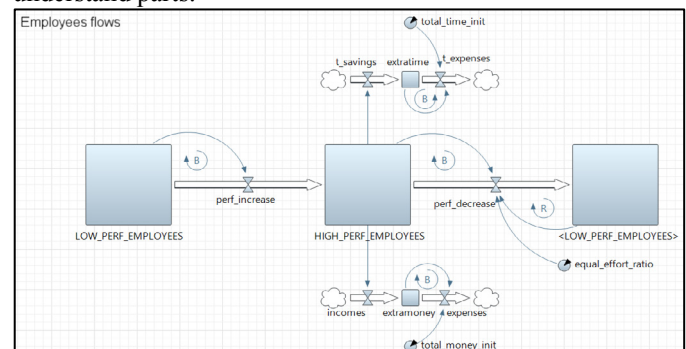


Fig. 2. SD sub-model employees.

5.2. Employee Performance Flows

Fig. 2 shows the stock and flows of employees between the two levels of performance, as well as the resources generated and used in the initiatives. There are two stocks representing the levels of performance: low performance and high-performance employees. The number of high performers affects the inflows of the resources, as the high performers generate additional value for the company. The focus is to test the feasibility of maintaining the initiatives only with these resources. Nevertheless, the inflows can also have fixed values or the resources stocks initial savings. The resources are expended depending on the active initiatives. The initiatives are activated when a percentage of the existing resources is expanded on them.

5.3. Leadership styles

The four leadership styles are included in the model. Each style can be activated or deactivated through a contribution parameter. The effect of each style in the performance increase flow, and is determined in the data gathering. Additionally, coaching uses the time resource and delegating the money resource (as discussed in the previous sections).

5.4. Time initiatives

Fig. 3 shows the sub model of the time initiatives. Each initiative has associated a parameter with the same name and the suffix “_init”. These parameters represent the percentage of current resources used on the initiative. The effect of parameters like task complexity or initial values of overtime or schedule pressure determine the values of the factors. There are variables that do not do so, instead will affect the EWB, present with the money initiatives. Additionally, the quality balancing loop deserves special attention since it is the only factor to introduce oscillations on the final levels of performance.

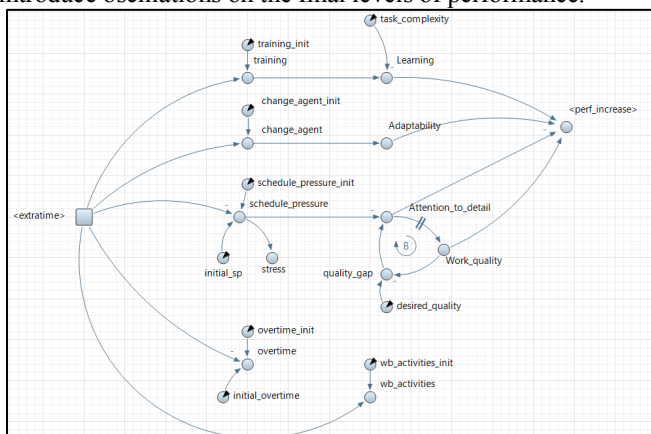


Fig. 3. SD sub-model time initiatives.

5.5. Capital investment related initiatives

Fig. 4 shows the sub model of the capital investment related initiatives. Each initiative has a parameter associated to assign a certain percentage of the resources to it. The informal and formal flexible working arrangements are modelled directly with a parameter that represents their impact as they do not require resources. Apart from the initiatives that end up affecting the performance increase flows, there are some that increase or reduce the performance losses. In particular, EWB affects it directly and through absenteeism.

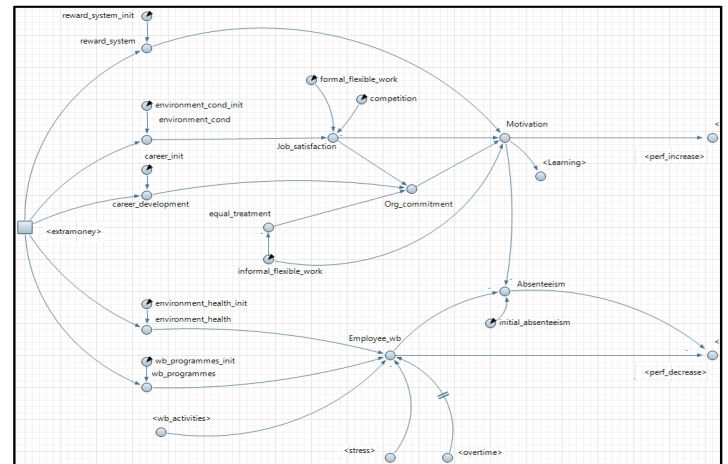


Fig. 4. SD sub-model capital investment related initiatives.

5.6. Experimentation

The model allows for a number of scenarios to be tested. For example, changing the initiatives, the leadership styles or fixed parameters like competition or levels of overtime. It can be used to simulate investments by adding fixed inflows of resources or initial quantities in the stocks, to give support to the initiatives until they become self-sustainable.

Table 1. Experiments.

Scenario
Exp1: Changing initiatives <ul style="list-style-type: none"> • Leadership style to “telling”. • Changing the career path initiative to reinforce both environment initiatives
Exp2: Resources investment (continuous) <ul style="list-style-type: none"> • Using current initiatives, but adding resources to reinforce them • Extra inflows of 10 time units and monetary units • Use of time initiatives
Exp3: Resources investment (initial) <ul style="list-style-type: none"> • Use current initiatives and add resources to reinforce them • Initial stocks of 100 time and 100 monetary units
Exp4: Resources investment (initial), focus on avoiding performance losses <ul style="list-style-type: none"> • Initial amount of resources increased to 1000. The total expense ratio of these resources has been reduced to 10% to avoid expending all of them in the first days • 3 performance losses to avoid: <ul style="list-style-type: none"> o Absenteeism – fixed at 5%, cannot be changed by initiatives o Equal effort – reduced by reaching high numbers of HP. o Employee well-being – to improve it, increase

6. Case study

To test the model developed, a case study was simulated. A senior manager was interviewed for collecting data for correcting the model, fix the equations, set the initial parameters values and choose the current initiatives. The company is a manufacturing SME with 40 employees, 25% of them considered as high performers initially. The high performers generate only monetary resources, so any time initiative had to be maintained by company investments. The company employ the telling and delegating leadership styles, although the employees do not find the latter beneficial. Schedule pressure is the only time initiative, although reducing overtime would be considered a priority if possible. The employees are under schedule pressure 60% of the time, and have overtime hours equal to 20% of their regular working hours. There is a quality control system to balance the attention to detail lost due to schedule pressure, although quality does not

directly affect performance. The average quality gap to the desired quality level is 10%. The only non-active monetary initiative is the well-being programmes, while the rest are all active, with special focus on the environmental initiatives. The company has neither formal nor informal flexible working arrangements, but also does not suffer significant competition. The absenteeism level is 5%. Employees are highly satisfied with their jobs and motivated by the reward system, but not by the career development. Finally, absenteeism does not seem to be affected by neither motivation nor EWB. Four experiments were tested (table 1).

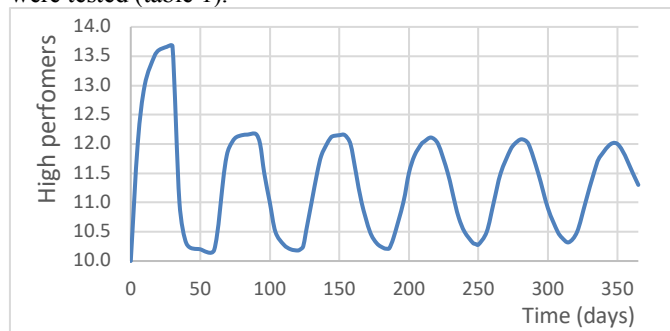


Fig. 5. As-is situation model predictions.

The starting point is to model the as-is situation. All the resources generated by the high-performance employees are used in the initiatives. Using the model developed, the high-performers stock was calculated for a year (fig. 5). There is an initial increase in the performance due to the initiatives. After one month, the quality control activates (the system checks the quality gap once a month and changes the attention to detail to reach the desired quality). This lowers the performance down to almost the initial value of 10 high performers. From that point, the performance oscillates around the 11 high performers value due to the quality control system. Compared to historic data, this proved to be the case for the organization verifying the validity of the model.

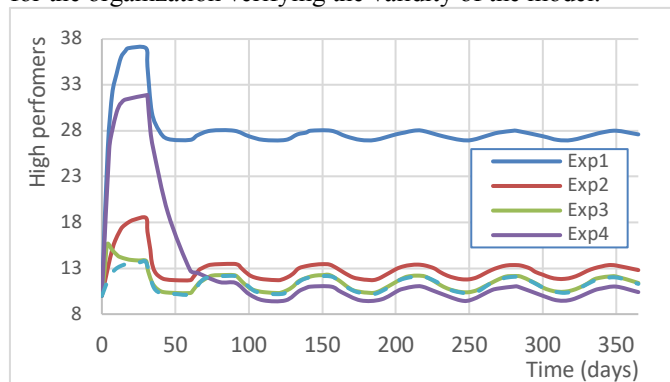


Fig. 6. Scenarios comparison.

Fig. 6 compares the outcome of the simulation of scenarios. Exp1 indicates that changing the initiatives results in higher number of high-performing employees. Again, when the quality control system is activated the average level of performance decreases by a significant amount and stabilizes with minor oscillations at 27 high performers. Exp2 shows that the speed in performance change is not affected by adding more resources. However, the number of high-performing employees is better compared to the as-is state.

Exp3 shows that the initial stocks greatly affect the speed at which the performance levels change. However, once they are consumed the performance slowly decreases to the same level as in current situation with no factors. Finally, Exp4 indicates that although the initial evolution of the performance levels is promising, after the first month there is a quick loss of performance resulting in a worse situation compared to as-is.

7. Conclusions and future work

A model was developed for simulating the impact of improvement initiatives on the employee performance. Such model can be used for comparing scenarios and help decide which one(s) to implement. In the current version, the model requires information to be collected from the company in order to inform the stock and flow equations. A number of assumptions are in place that will be further considered. Indicatively, aspects that need to be further modelled include:

- The turnover of staff will affect the performance changes. Employees leaving or joining the company will affect performance differently depending on which level of performance they were in or they start in
- New employees commonly go through a training period (different from the training initiatives in the model). While they are integrated in the company, the effects of the initiatives on them will vary
- The external environment was not considered, but its potential impact on an employee's performance should not be disregarded.
- The sustainability of the initiatives depends on the extra resources generated by the high performers. However, these will change depending on the general business condition.

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