Proposing a Smart Performance Management System for Production Workshop Based on Virtual Organizational Deoxyribonucleic Acid Concept

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Abstract:

This research aims to develop and validate a smart PMS. The PMS will create a foundation for PMSs that will be used by organizations in the digital era. A three-step methodology was used in the current research. First, the archival literature analysis was used to identify the features and elements of the robust PMSs. Second, a generic PMS was constructed based on the results of the first step. Third, the generic PMS was amended, implemented in the workshop, and validated by discussing the results with a focus group of experts. The academic and technical contribution can be seen in proposing a generic Virtual Organizational Deoxyribonucleic Acid (V-DNA) concept and smart PMS (Performance Management Dashboard (PMD) and Decision-Making Tool (DMT)) based on the features and elements of the robust PMSs. The generic V-DNA and PMS were amended and implemented in the stated workshop. Then, the validation process was done by presenting the implementation results to a focus group of academic experts and taking their feedback. Applying the PMD and the DMT to monitor, analyze, and manage workshop performance was successful. The PMD proved a useful tool that can provide a holistic view of the workshop performance areas instead of focusing on isolated business aspects such as workshop productivity or efficiency. The decision-makers directly identified the low-performing and highly performing KPIs/processes/sub-processes and identified the root causes of low and high performance. The DMT proved a useful tool. The decision-makers could evaluate all sub-processes and rank them based on the values and weights of the decision-making criteria, highlighting the areas that need improvement. The originality and novelty of the proposed PMS and the V-DNA were proved through a systematic literature review process. The implications of the research can be seen in the possibility of testing the generic V-DNA and the PMS templates in organizations of different sizes and sectors to check their applicability. Moreover, other layers of the organizational V-DNA can be proposed. The current research assists the practitioners and managers in constructing the PMSs they need for their workshops/factories/companies.

Keywords: Organizational Performance, Organizational Virtual DNA, Performance Management System, Dashboard, Decision-Making Tool, Business rocess

اقتراح نظام ذكي لإدارة الأداء المؤسسي لورشة عمل أنتاجية على أساس مفهوم الحمض النووي الافتراضي

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الخلاصة:

يهدف هذا البحث إلى تطوير نظام إدارة أداء ذكي والتحقق من صحته. سيعمل نظام إدارة الأداء (PMS) كقاعدة لأنشاء أنظمة ذكية لإدارة الأداء (PMS) التي ستستخدم من قبل المؤسسات في العصر الرقمي. تتكون منهجية

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البحث من ثلاث خطوات. أولاً، تم تحليل الأدبيات لتحديد ميزات وعناصر أنظمة إدارة الأداء المتقدمة. ثانياً، تم إنشاء نظام إدارة اداء بناءً على نتائج الخطوة الأولى. ثالثًا، تم تعديل نظام إدارة الأداء المطوروتنفيذه في أحد الورش الانتاجية، والتحقق من صحته من خلال مناقشة النتائج مع مجموعة من الخبراء. تتمثل المساهمة الأكاديمية والفنية في اقتراح مفهوم عام للحمض النووي الافتراضي (V-DNA) ,تطوير نظام أدارة أداء ذكي , تطويرلوحة قيادة ذكية لنظام أدارة الاداء , وتطوير أداة صنع القرار استنادًا إلى ميزات وعناصر أنظمة إدارة الأداء المتقدمة. تم تعديل و تطبيق نظام أدارة الاداء المطور على الورشة الانتاجية المذكورة. بعد ذلك، تمت عملية التحقق من فعالية النظام من خلال عرض نتائج التطبيق على مجموعة من الخبراء الأكاديميين وأخذ ملاحظاتهم. كان تطبيق لوحة القيادة الذكية وأداة صنع القراررلرصد وتحليل وإدارة أداء الورشة المذكورة ناجحًا. لقد أثبت تطبيق لوحة القيادة الذكية أنها أداة مفيدة يمكن أن توفر رؤية شاملة لمجالات الاداء كافة بدلاً من التركيز على جوانب عمل محددة كإنتاجية الورشة أو كفاءتها. حدد صناع القرار بشكل مباشر مؤشرات الأداء الرئيسية / العمليات / العمليات الفرعية ذات الأداء المنخفض والعالي، وحددوا الأسباب الجذرية للأداء المنخفض والعالي. أثبت تطبيق أداة صنع القرارأنها أداة مفيدة. يمكن لصانعي القرار تقييم جميع العمليات الفرعية وترتيبها بناءً على قيم وأوزان معايير اتخاذ القرار، مع تسليط الضوء على المجالات التي تحتاج إلى تحسين. تم إثبات أصالة وحداثة نظام أدارة الاداء المطور و مفهوم الحمض النووي الافتراضي من خلال عملية مراجعة منهجية للأدبيات. يمكن رؤية الآثار المترتبة على البحث في إمكانية تطبيق وأختبار نظام أدارة الاداء المطور و مفهوم الحمض النووي الافتراضي في منظمات ذات أحجام مختلفة وقطاعات أعمال مختلفة. علاوة على ذلك، يمكن اقتراح طبقات أخرى من مفهوم الحمض النووي الافتراضي. يساعد البحث الحالي الممارسين والمديرين في بناء أنظمة إدارة الأداء الذكية التي يحتاجونها لشركاتهم.

1 Introduction

Performance Management Systems (PMSs) are important tools for monitoring, assessing, and managing processes' performance [1]. Organizational Performance (OP) is defined as a "measure of how well organizations are managed and maximize the value they deliver to customers and other stakeholders" [2], page 43. The PMS is also defined as a set of processes, systems, and mechanisms that organizations use to translate strategic goals into operational objectives and manage them through the "analysis, planning, measurement, control, rewarding, and broadly managing performance, and for supporting and facilitating organizational learning and change" [3], page 9.

A thorough literature review was conducted to identify the PMSs' literature strengths, weaknesses, and limitations. Moreover, the literature was analyzed to determine the features/elements of the robust PMSs. Developing PMSs/Performance Management Dashboards (PMDs) attracted considerable interest in many business sectors. For instance, the PMSs/PMDs were designed and implemented in the construction sector [4], educational sector [5]–[8], general trading sector [9], the health sector [1], [10], [11], hospitality sector [12], etc. However, it was confirmed through the systematic literature review that the reviewed literature lacks a smart PMS that can create a foundation for PMSs to be used by organizations in the digital era.

Building on the above-stated facts, this research aims to develop and validate a smart PMS. The PMS will create a foundation for PMSs that will be used by organizations in the digital era. The PMS will be implemented in a case study production workshop in the headquarters factory of an international cold merchandising equipment manufacturing (CMEM) company. The PMS will be constructed on the workshop level because of the complexity of the PMS development and validation process. Future work will apply the proposed PMS to the other factory departments and company branches. The proposed PMS will be constructed based on the stated features and elements of robust PMSs. Three objectives were derived to fulfill the goal of the research. These objectives are (1) identifying the features and elements of the robust PMSs, (2) proposing a generic PMS template, and (3) testing the proposed PMS template in the stated production workshop and validating it through a focus group discussion.

The company headquarters is in the United Arab Emirates (UAE) and has many branches in many other countries. The company moved from the local to international markets and urgently needs an effective and smart PMS to support the organization's efforts in overcoming the aggressive competition and challenging business environment, especially with the fourth industrial revolution. The production workshop employed more than 300 workers, 25 supervisors, and five engineers. The daily production rate of the workshop is almost 300 from different models of cold merchandising equipment.

The academic (technical) contribution of the current research can be seen in proposing a generic Virtual Organizational Deoxyribonucleic Acid (V-DNA) and PMS (PMD and Decision-Making Tool (DMT)) templates based on the features and elements of the robust PMSs. V-DNA is an effective approach used in many areas to store the objects/processes/systems' historical developments and the decisions related to these developments and

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recall them. It provides the decision-makers with a deep understanding of these objects/processes/systems and facilitates the decision-making process that initiates relevant improvement projects [13]. The current research assists the practitioners and managers in constructing robust PMSs they need for their workshops/factories/companies to overcome the challenges that come with the fourth industrial revolution. The generic templates were amended and implemented in the stated production workshop. Then, the validation process was done by presenting the implementation results to a focus group of academic experts and taking their feedback.

The paper structure consists of seven sections. After the introduction, the research methodology was discussed in the second section. After that, the literature was reviewed and analyzed, and the results were presented in the third section. The design and implementation of the PMS were introduced in the fourth section. Finally, the research results were discussed in the fifth section, the implications and limitations were presented in the sixth section, and the conclusions were summarized in the seventh section.

2 Research Methodology

After introducing the research background and the facts that motivated researchers to conduct this research and setting the research aim and objectives, the methodology used in the current research consists of three steps. First, the archival literature analysis methodology will be used for analyzing the available literature to fulfill the first research objective. Second, a generic PMS template will be constructed based on the results of the first step of the methodology. Third, the proposed PMS will be amended, implemented in the production workshop, and validated by a focus group discussion. The details of the research methodology are shown in Figure (1.

3 Literature Review

A systematic literature review (SLR) will be conducted. The systematic literature review process will follow the reference [14] approach. This approach was adapted initially from the reference [15]. The SLR process encompasses the problem formulation, data collection, data evaluation, analysis and interpretation, and public presentation stages. The details of the literature review process are shown in the following sections.

3.1 Problem Formulation

The literature review aims to fulfill the first research objective. The following research question will be derived to guide the literature review process.

What are the features and elements of robust PMS?

3.2 Data Collection

The Google Scholar search engine was used as a gate to collect the papers from many other databases. Google Scholar database allows access to a broad spectrum of articles/journals and is linked to much more scientific databases. Moreover, the reader will access any article citing the article under review or cited by the paper under review. The patents and citations were excluded from the search results because the current research only focuses on journals and conferences. The search mode "phrase" And/Or "phrase" was used to avoid including irrelevant terms that may mislead the review process and narrow the search results to publications related to the research scope. Therefore, the keyword used for the search was "Organizational Performance" AND "Business process" AND "Performance Management System" OR "Performance Management Dashboard".

There is no limit to the period to be included in the search results. Using the above-stated keywords resulted in 3030 results on May 30, 2023. The search results were screened until no relevant results could be identified. The identified papers were published between 2000 and 2022, i.e., 22 years. Applying the selection criteria shown in

Table (1 resulted in the selection of 84 publications. These papers will be analyzed to extract the needed information. The extracted results will be used to answer the research question and fulfill the research objectives.

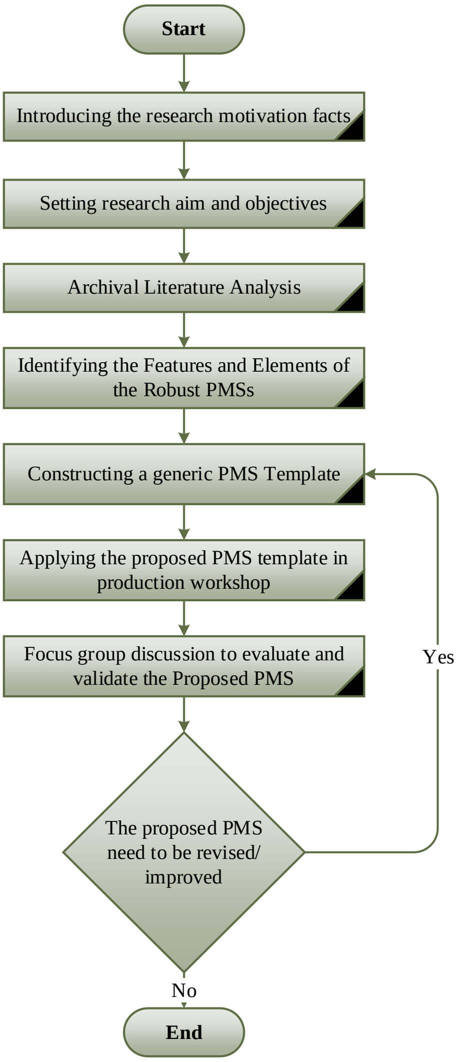

Figure (1): Research Methodology

3.3 Data Evaluation

The authors have reviewed the titles and abstracts of the articles from the search results to identify the articles relevant to the literature review objectives. Moreover, the papers were thoroughly reviewed if the title and abstract review did not clarify the paper's scope. Following the reference [14] approach, the outcomes of the review process were discussed and agreed on to accomplish the reliability of the review and selection process. As stated in the previous section, 84 papers were selected. These papers were reviewed and categorized by the business sector, as shown in Table (2. The information in Table (2 shows the diversity, inclusion, and high quality of the selected publications.

3.4 Analysis and Interpretation

This section aims to analyze the literature listed in the data evaluation section to build the necessary conclusions and answer the literature review question. Regarding the features and elements of the robust PMSs, Ubaid and Dweiri (2020) analyzed the Business Process Management (BPM) literature and shortlisted the main elements of the PMSs. The elements encompass vision, mission, goals, Critical Success factors (CSFs), organization processes and sub-processes structure, Performance Measures (PMs), Key Performance Indicators (KPIs), and Aggregated Organizational Performance (AOP) [16]. An effective PMS system should reduce the complexity of performance management and decision-making process [17] and support organizations in the digital transformation agenda [18].

Table (1): Data Collection Stage-Search words, mode, criteria, and results

Search word(s)	Search mode	Search Criteria	Selection Criteria	Results	Date of search
1. Organizational Performance 2. Performance Management System 3. Performance Management Dashboard **4.** Business process	"phrase" And/Or "phrase"	1. All papers elements 2. Patents and citations excluded 3. No limit to the period to be included in the search results	Only peer-reviewed articles from academic journals and conferences that fall within the scope of the current research are selected. Relevant book chapters may be included	Only 84 papers were selected for review after excluding all irrelevant publications.	May 30, 2023

Table (2): The reviewed literature categorized by the business sector.

Business sector	Papers number	% of papers /Business sector	Reference
Agro-Industry	1	1.19%	[19]
Air transport	1	1.19%	[3]
Banking Industry	1	1.19%	[18]
Construction	3	3.57%	[4], [20], [21]
Educational	6	7.14%	[5]–[8], [22], [23]
Energy sector	5	5.95%	[24]–[28]
Exhibition	1	1.19%	[29]
Food Industry	1	1.19%	[30]
Generic	23	27.38%	[16], [31]–[52]
Healthcare	3	3.57%	[1], [10], [53]
Hospitality	1	1.19%	[12]
Inspection bodies	1	1.19%	[54]
IT	3	3.57%	[55]–[57]
Logistics	2	2.38%	[58], [59]

Manufacturing	15	17.86%	[2], [9], [17], [60]–[71]
Non-Profit Organizations (NPO)	3	3.57%	[72]–[74]
Product development	1	1.19%	[75]
Public sector	4	4.76%	[76]–[79]
Retail	1	1.19%	[80]
Supply chain	4	4.76%	[81]–[84]
Telecommunication	2	2.38%	[85], [86]
Telesales	1	1.19%	[87]
Water management	1	1.19%	[88]

The literature analysis showed the importance of having effective, dynamic, flexible PMS for measuring, monitoring, and improving the OP [9], [52]. The PMS should be characterized by its real-time monitoring capability [6], [7], [12], [33], [72], transparency, and accountability [77]. An effective PMS should link the organization's strategy with operational-level activities [10], [23], [35], [63], [82], and the KPIs, and PMs should measure the financial and non-financial business aspects [2], [38], [60], [61], [85]. Moreover, the PMS should provide quick, straightforward feedback [21].

The robust PMS should provide the ability of a visual presentation of the measured PMs, KPIs, other performance elements, and the correlation between them [8], [9], [57]. In other words, the PMS should have a PMD to help organizations focus on the right business aspects, enhancing PMS effectiveness and supporting decision-making accuracy [56]. The essential elements of the PMD mentioned in the literature include (1) the hierarchy of the business processes, (2) the performance value for the AOP, the KPIs, the processes, and the sub-processes, (3) the correlation relationships between the processes and the KPIs [5], [7], [32], [33], [63], [72], (4) CSFs [26], [68]. The PMS elements should be connected through a set of mathematical equations [61], [62], [89]–[91].

Decision-making tools are considered one of the essential elements of robust PMS. The literature review revealed using many decision-making tools to design and construct PMSs, support the decision-making process, and select improvement projects as a part of the performance management and improvement process [38], [54], [71], [84], [88]. Therefore, proper decision-making tool/s are mandatory to enhance PMSs' efficiency and effectiveness. The PMSs must be constructed using a systematic and scientific approach/framework/methodology [17]–[19], [21], [50], [55].

Regarding the PMS feature related to supporting organizations' efforts for digital transformation in the digital era, which is highlighted by the reference [18], the literature revealed that most of the PMSs available in the reviewed literature lack the necessary element to fulfill this feature. V-DNA is one of the approaches used in the literature to build a digital organization and manage it efficiently. It is based on the concept of creating a knowledge-based database to store the objects/processes/systems' historical developments and the decisions related to these developments and recall them when they are needed to make new decisions/improvements. It provides the decision-makers with a deep understanding of these objects/processes/systems and facilitates the decision-making process that initiates relevant improvement projects [13].

Viewing organizations as living organisms and developing a V-DNA [92]–[96] is a novel and effective approach of creating knowledge structures and use these structures to facilitate the decision-making process. However, the concept of developing a V-DNA structure and using it to manage and improve the OP wasn't used before in the reviewed literature. This result complies with the results of the reference [97]. Therefore, this approach will be used to enhance the efficiency and effectiveness of the proposed PMS and fill the stated gap.

3.5 Literature Review Results Presentation

This section aims to present the results of the literature review analysis and answer the research question. The research question was, "What are the features and elements of robust PMS?". Based on the conducted analysis, the elements of the robust PMS are summarized in Table (3, and the features of the robust PMS are summarized in

Table (4. The first research objective is fulfilled based on the literature review process outcomes presented in this and previous sections.

Table (3): The elements of the robust PMS

No#	Elements of the robust PMS
1	Vision, mission, goals, and CSFs.
2	Organization processes and sub-processes structure.
3	PMs, KPIs, and AOP.
4	PMD. The essential elements of the PMD mentioned in the literature include (1) the hierarchy of the business processes, (2) the performance value for the AOP, the KPIs, the processes, and the sub-processes, (3) the correlation relationships between the processes and the KPIs, (4) CSFs.
5	The PMS elements should be connected through a set of mathematical equations.
6	Decision-making tools
7	The knowledge-based database is mandatory to store the objects/processes/systems' historical developments and the decisions related to these developments and recall them when they are needed to make new decisions/improvements. A V-DNA for organizational Performance management will be proposed. The elements of the organizational V-DNA include GI and EI of vision, mission, goals, CSFs, organization processes structure, sub-processes, PMs, KPIs, AOP, and the relationships between these elements.

Table (4): The features of the robust PMS

No#	Features of the robust PMS
1	PMS systems should reduce the complexity of performance management and decision-making process.
2	PMS should support organizations in the digital transformation agenda.
3	PMS should be effective, dynamic, and flexible in measuring, monitoring, and improving the OP.
4	PMS should be characterized by its real-time monitoring capability.
5	PMS should be characterized by its transparency and accountability.
6	PMS should link the organization's strategy with operational-level activities.
7	KPIs and PMs should measure the financial and non-financial business aspects.
8	PMS should provide quick and straightforward feedback.
9	PMS should provide the ability of a visual presentation of the measured PMs, KPIs, other performance elements, and the correlation between them.
10	PMSs must be constructed using a systematic and scientific approach/framework/methodology
11	PMSs must be built based on sustainability principles

4 Materials and Methods

4.1 The Virtual Organizational Deoxyribonucleic Acid (V-DNA) structure

To construct the V-DNA, the elements of the V-DNA must be defined. Most of the V-DNAs of the products presented in the literature consist of the Genetic Information (GI) and the Evolutionary Information (EI) of the products' information. The GI includes all information required to reproduce the product, such as parts list, shapes, dimensions, materials, units, the manufacturing processes for each part, and the relationships between the products' parts and units. On the other hand, the EI includes all historical information related to the products from the first product design until the latest product version [94], [98]. Others added the product tolerances features [96], products' manufacturing processes information, product quality characteristics, product quality characteristics precision, and the quality characteristics influence factors [95].

The V-DNA structure of the engineering processes encompasses the manufacturing operations information, resources/machines information and the process level decisions information. The V-DNA structure is described as an experience-based knowledge representation of the engineering processes because it provides the company with a virtual environment of the manufacturing processes, which will support the decision-making process and optimize resources utilization and planning processes [93]. The other levels of the V-DNA structure encompass the decisions made regarding the loading/unloading work, transporting work, temporary storage, and quality control [13].

Often, any organization's main unit/process consists of sub-processes. Therefore, improving and controlling the sub-processes' performance will ultimately contribute to the main unit/process performance, OP, and help the organization reach the desired outcomes [99]. On the performance management/organizational excellence research scope, the organizational V-DNA elements should include all elements related to managing and monitoring OP (GI and EI). Therefore, based on the stated features of the V-DNA [94] and the elements needed for managing the OP [16], the elements of the organizational V-DNA include GI and EI of vision, mission, goals, CSFs, organization processes structure, sub-processes, PMs, KPIs, AOP, and the relationships between these elements.

It is obvious that the core element of constructing the V-DNA for PMS is the organization's processes because it represents the factor connecting all organization's elements vertically and horizontally. Therefore, the organizational V-DNA for PMS will be constructed based on the organizational processes' structure. A business process can be defined as dynamically coordinated activities or logically related tasks characterized by their cross-functional nature. The process links organizations' operations with organizations' goals and objectives/customers' requirements [100].

The current research will create a foundation to develop a comprehensive DNA template of any organization, encompassing all organization levels considering the necessary correlations between all units and levels. Based on the V-DNA definition provided in the literature analysis section and the elements of the V-DNA shown in the above paragraphs, the proposed structure of the V-DNA is shown in Figure (2. The proposed V-DNA will be used as a baseline in constructing the PMD within the PMS. PMD will monitor the GI and the EI of the OP, the KPIs performance, the main processes performance, the sub-processes performance, and highlight the correlation between these processes.

4.2 Mathematical Structure of the PMS

The mathematical structure of the PMS will be presented in this section. Based on the literature analysis results, a set of equations were extracted to calculate the performance values on different system levels and normalize the measured PMs values. Equation (1) is used to calculate the sub-process aggregated performance value, equation (2) is used to calculate the main processes performance value [61], [62], equation (3) is used to calculate the KPIs' aggregated performance value, and the equation (4) used to calculate the AOP value [61]. The normalized PMs' values are calculated based on the measured PMs' values from the processes, and they were normalized by the appropriate normalization functions [90].

$$SPP = \sum_{i}^{n} LPMW_i * PM_i \text{ .... (1)}$$

Where the variable *SPP* represents sub-process performance. The variable PM_i represents the normalized PM value of the individual PM, and the variable $LPMW_i$ means the local weight of that individual PM.

$$PP = \sum_i^n SProW_i * SPP_i \quad \text{.........} \quad (2)$$

The variable *PP* represents the main process performance. The variable SPP_i represents the performance value of the individual sub-process, and the variable $SProW_i$ means the weight of that individual Sub-Process.

$$KPI = \sum_i^n GPMW_i * PM_i \quad \text{.........} \quad (3)$$

The variable PM_i represents the normalized PM value of the individual PM, and the variable $GPMW_i$ means the global weight of that individual PM.

$$AOP = \sum_i^n W_i * KPI_i \quad \text{.........} \quad (4)$$

The variable *KPIi* means the KPI value of the individual KPI. The variable *Wi* means the weight of that individual KPI.

The weights of PMs represent the contribution percentages to the KPI or the sub-processes' performance, calculated by multiplying the PMs' contribution percentages by one [89], [101]. Hence, there will be local PMs' weights related to the sub-processes and global PMs' weights related to the KPIs, i.e., the contribution of these PMs to the sub-processes performance or the KPIs' performance.

The global PMs weights mean the PMs' weights based on their importance for the KPI related to those PMs. The local PMs weights represent the weights allocated to each PM within each sub-process based on each PM's importance for each sub-process. A similar approach will be used for setting sub-processes weights to measure the main processes' performance.

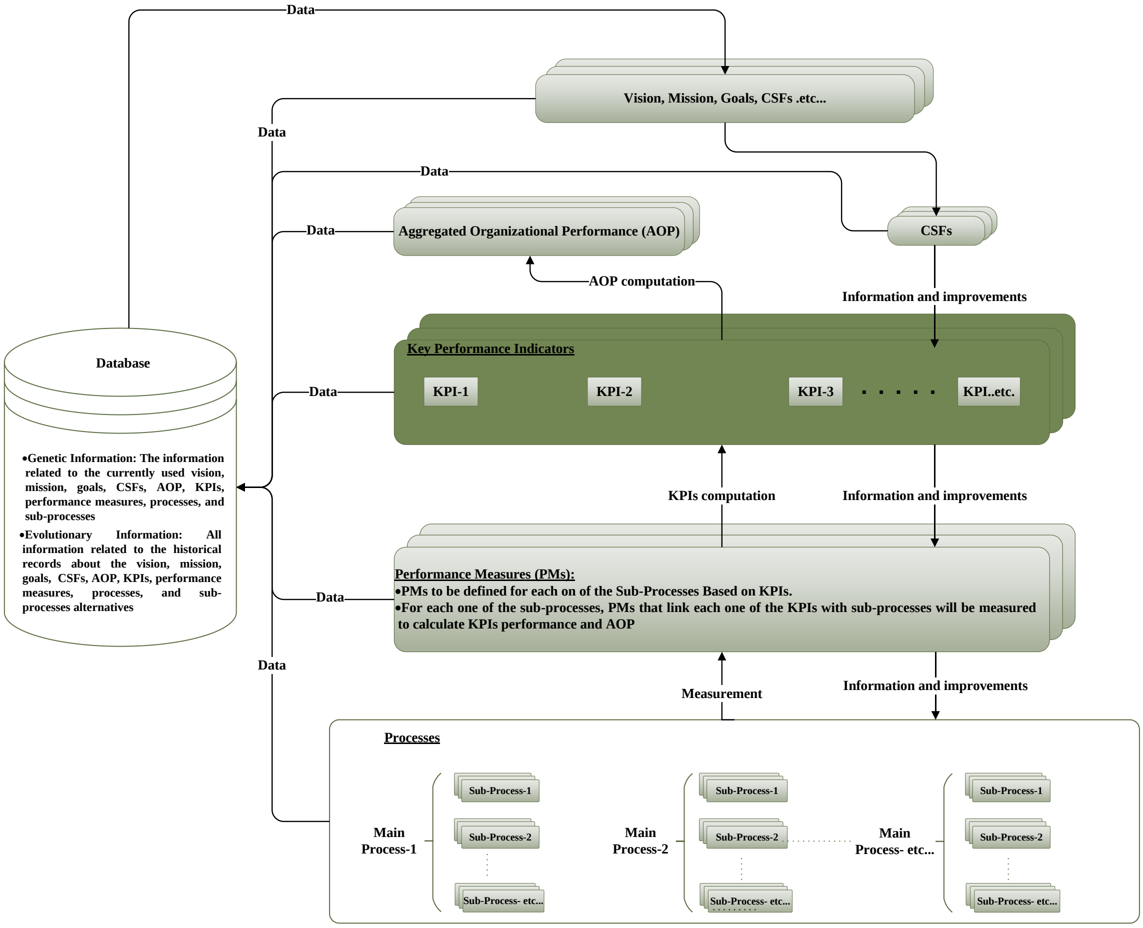

Figure (2): The proposed V-DNA structure.

4.3 Decision-Making Tools (DMT) for PMS

Regarding the decision-making tools that will be used in the PMS, the Analytic Hierarchy Process (AHP) method will be used to calculate the weights of the decision-making criteria. The Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS) method will be used to facilitate the decision-making process of selecting the sub-processes that should go through the improvement process. Moreover, the TOPSIS method will be used to facilitate the decision-making process of selecting the proposed solutions based on the improvement projects.

The hybrid AHP-TOPSIS method used by many researchers in MCDM problems such as machining parameters optimization [102], ranking human capital indicators [103], designing high-performance concrete mixtures [104], improving cities sustainability [105], etc., and proved as a robust research method. Therefore, it will be used to construct the DMT.

Based on the literature analysis, the process shown in Figure (**3** proposed to identify, evaluate, and select the relevant KPIs/PMs. The AHP method and the correlation analysis technique will be used to rank the KPIs/PMs/sub-processes and identify the relationships between the KPIs/PMs/sub-processes. The regression analysis technique [106] will be used to determine the relationships between the KPIs and the overall OP, between the PMs and the sub-processes, between the PMs and the KPIs, and between the sub-processes and the main processes. The regression analysis technique will facilitate the process of computing the contribution percentage.

4.4 Performance Management System Construction

Many systematic approaches were used in the literature for constructing the PMSs. The Integrated Performance Management System (IPMS) framework [107] will be used in the current research for constructing the PMS because it is one of the tested and proven efficient frameworks in many high-quality research publications. The IPMS framework encompasses a five-stage approach to building and validating the PMS. The stages are the foundation stage, information collection stage, PMS design stage, implementation stage, and continuous improvement stage. More specifically, the following sections will present the process of constructing and validating the PMS (PMD and DMT) to fulfill the second and third research objectives.

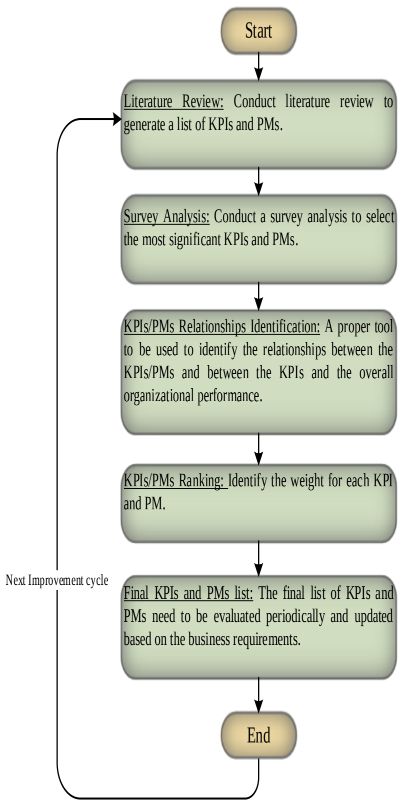

Figure (3): KPIs identification process flow.

4.4.1 Foundation Stage

The PMS will be constructed based on the features and elements of the PMSs presented as outcomes of literature analysis. Moreover, the proposed V-DNA structure, the mathematical structure, and the stated decision-making tools will be used as foundations for constructing the PMS (PMD and DMT). It is important to explain that other PMS elements will be embedded in the PMD and DMT. The proposed PMS (PMD and DMT) will be generic to allow other researchers to follow the same steps for constructing PMSs for other organizations. Then, the generic PMS will be tested by applying it in the stated production workshop and validating it through a focus group discussion which will fulfill the third and fourth objectives. The future work will focus on testing the proposed generic PMS model by using it for other manufacturing companies and organizations from different business sectors.

4.4.2 Information Collection Stage

The V-DNA structure shown in Figure (2 represent the description of the structure and the details of the information required to construct any V-DNA. This information will be used for constructing the PMD and feeding the data to the DMT within the PMS. The core element of the V-DNA structure is the organization's processes, as was discussed previously. The elements of the V-DNA include GI and EI of vision, mission, goals, CSFs, organization processes structure, sub-processes, PMs, KPIs, AOP, and the relationships between these elements. The first layer of information in the V-DNA structure represents the GI information, and the other layers represent the EI. PMD will monitor the GI and the EI of the OP, the KPIs performance, the main processes performance, the sub-processes performance, and the correlation between these processes.

4.4.3 Design Stage

4.4.3.1 Designing the Performance Management Dashboard (PMD)

Based on the analysis and information in the previous sections, the first element in the PMD is the KPIs. Any organization that uses the PMD should amend the PMD based on its V-DNA structure. The PMD will consist of a group of platforms. The platforms of the PMD will be described in the following sections.

- ***Data entry platform***

The data entry platform feeds the information to the computation platform. The information includes the measured PMs values, sub-processes weights in main processes performance, the percentage of each PM contribution to sub-processes performance, the percentage of each PM contribution to KPIs performance, the KPIs' weight in the AOP, and the correlation analysis results. In addition, the data entry platform feeds other information to the PMD. This information includes KPIs names and descriptions, main processes names and descriptions, sub-processes descriptions, PMs descriptions, PMs computation formulas, PMs unit of measurement, and PMs normalization functions to use for the computation process and record it in the EI database.

- ***Computation Platform***

The computation platform is used within PMD to normalize PMs measured values, calculate PMs weights, sub-processes performance values, main processes performance values, KPIs performance values, and the AOP values. The computation process flow is shown in Figure (4. Equations 1, 2, 3, and 4 are used in the computation process. Moreover, the data collected from calculating the performance values of the sub-processes, main processes, and KPIs will be stored in the PMD database and used to conduct the correlation analysis after accumulating enough data. The correlation analysis is necessary to identify the correlation between the sub-processes, identify the correlation between the KPIs, feed the data to the PMD, and use them to calculate the criteria that will be used in the DMT. The details of the decision-making criteria will be explained in the DMT section.

- ***Genetic Information (GI) Dashboard platform***

Referring to the organizational V-DNA stated concept and discussed details of the GI and EI, the GI dashboard will visually present the organization processes’ structure but not necessarily represent the processes flow. PMD structure shows the hierarchy of the processes and the performance value for the AOP, the KPIs, the processes, and the sub-processes. The activities presented in the computation platform section will be used to compute the details shown in the GI dashboard. The first part of the GI dashboard is a performance dashboard.

In the performance dashboard, the presented performance values, on all levels, represent the GI of the V-DNA, i.e., it shows the performance values of the currently running processes, sub-processes, KPIs, and the AOP. However, for future developments, the current GI information will be EI. Another vital part of the GI dashboard is the correlation dashboard. The organizations will conduct correlation analysis and feed the results to the data entry platform using the KPIs and the sub-processes accumulated performance records. The correlation analysis results will be used in the computation platform and shown in the correlation dashboard.

- ***Evolutionary Information (EI) Database platform***

Based on the V-DNA concept, the other important part of PMD is the EI database. EI database will contain complete records of the historical developments/improvements of the sub-processes and the historical performance records. After each performance measurement cycle, the measured performance values with all related information will be recorded in the EI database. The PMD users should record the newly developed sub-processes, define the new sub-processes' description, record the new sub-processes weights to replace the old weights, define the new sub-processes PMs, and define the PMs' contribution to the KPIs performance. The latest developed/improved sub-processes will be added as genetic information in the GI dashboard, data entry, and computation platforms.

In contrast, the old sub-processes will be recorded as EI in the EI database to be used by the organization as needed. Moreover, decision-making criteria data will be recorded in the EI database. The organization that uses the PMD will use the data of the decision-making criteria available in the EI database and the DMT to select the sub-processes that represent potential improvement areas or choose the best alternative among the tested alternatives during improvement projects.

4.4.3.2 Designing the Decision-Making Tool (DMT)

The DMT is designed to take two types of decisions. For the first decision, the alternatives are the sub-processes available in the organization GI within the sub-processes structure. For the second decision, the alternatives are the set of available solutions selected through improvement projects to replace/improve low-performing/conflicting sub-processes chosen during the first decision-making process. The criteria used in the DMT encompasses five criteria. The first criterion is the average of the sub-processes' negative correlation. The logic of using this criterion is that the higher absolute value of the average negative correlation of any sub-process, i.e., closer to -1, indicates that this sub-process has a significant negative effect on the other sub-processes compared to the other sub-processes. Therefore, organizations need to focus on this sub-process and improve it/replace it to minimize the negative effects as much as possible.

The second criterion is the average of the sub-processes' positive correlation. The average value of each sub-process positive correlation with other sub-processes will be used as a criterion in the DMT. The higher the value of the average positive correlation of any sub-process, i.e., closer to +1, indicates that this sub-process has a significant positive effect on the other sub-processes compared to the other sub-processes with low average values. Therefore, organizations need to focus on this sub-process and maximize performance value as much as possible if the performance value is low.

The third criterion is the average of the sub-processes' contribution to the KPIs' performance. Based on the PMD data, the average of each sub-process weight in the KPIs performance will be calculated and used as a criterion in the DMT. The higher average value means this sub-process will significantly affect the KPIs' performance and AOP. Therefore, organizations need to focus on this sub-process and maximize performance value as much as possible if the performance value is low.

The fourth criterion is the sub-process weight in the main process performance. Each sub-process's weight in the main process, where this sub-process belongs, will be used as a criterion in the DMT. The higher sub-process weight means that this sub-process will significantly affect the performance of the main processes. Therefore, organizations need to focus on this sub-process and maximize performance value as much as possible if the performance value is low.

The fifth criterion is the sub-process performance value. Performance value is the classical criterion widely used in decision-making processes. Logically, the sub-processes that have low-performance scores should be subject to improvement. Therefore, this criterion will be used as a criterion in the DMT.

The decision-making process hierarchy is shown in Figure (5, and the DMT process flow is shown in Figure (6. The AHP method logic is used to create a template within the DMT and set the weight for the DMT's criteria. TOPSIS is the MCDM method used to find the best alternative with the shortest distance from the positive ideal solution and the farthest distance from the negative ideal solution.

4.4.4 Implementation Stage

The purpose of this section is to amend the generic V-DNA, PMD, and DMT presented in the previous sections to construct the smart PMS for the production workshop. Then, implement the amended PMS (V-DNA, PMD, and DMT), and validate it through a focus group discussion. The name of the organization is withheld due to confidentiality. The case organization already has a vision, mission, goals, and objectives, and they have identified their CSFs.

Previously, before applying the proposed PMS, the performance of the workshop was measured using three major KPIs. These KPIs include productivity, financial revenues, and employee performance. Therefore, to amend and use the generic PMS proposed in the current research, organization management has followed the guidelines given in this research to identify the information required for amending and using the generic PMS elements.

The information collected during the work with the workshop team includes the organization's vision, mission, goals and objectives, CSFs, KPIs, main processes information, sub-processes information, the weight allocated to the sub-processes within each of the main processes, and the PMs. Moreover, for a specific timeframe, the data of the measured PMs values were collected and used to calculate the performance of the KPIs, the main processes, and the sub-processes, and calculate the correlation coefficients between the KPIs and between the sub-processes.

4.4.4.1 V-DNA Amendment and Implementation

The generic V-DNA structure was amended based on the workshop data, resulting in the workshop V-DNA creation. However, because of the complexity of the V-DNA structure, only a simplified presentation of the workshop GI was presented in this research, as shown in Figure (**7** and Figure (8. The implementation process showed that the V-DNA concept is applicable and valuable for developing an experience-based knowledge structure that systematically stores and reuses historical information to facilitate decision-making.

4.4.4.2 PMD Amendment and Implementation

The generic PMD was amended using the production workshop GI V-DNA information and two years' records of the PMs' measured values for all sub-processes in the workshop. The PMs' measured values won't be shared because of confidentiality issues. The historical records were recorded on the data entry platform. Then, the performance values of the KPIs, main processes, and sub-processes are computed in the computation platform. The outcomes of the computation process were presented in the GI dashboard and stored in the EI database. After that, the correlation analysis between the KPIs and between the sub-processes was performed using the results stored in the EI database and presented in the GI dashboard.

The results of computing the aggregated workshop performance, the KPIs' performance, the main processes' performance, and the sub-processes' performance are presented in the GI dashboard and are shown in Figure (9. A sample of the KPIs' correlation analysis results and the sub-processes correlation analysis results are presented in the GI dashboard and are shown in Figure (10 and Figure (11. These figures show that the dashboard visualizes the workshop performance on all levels. It facilitates the decision-makers' mission to identify the low-performing areas/processes and highly-performing areas/processes.

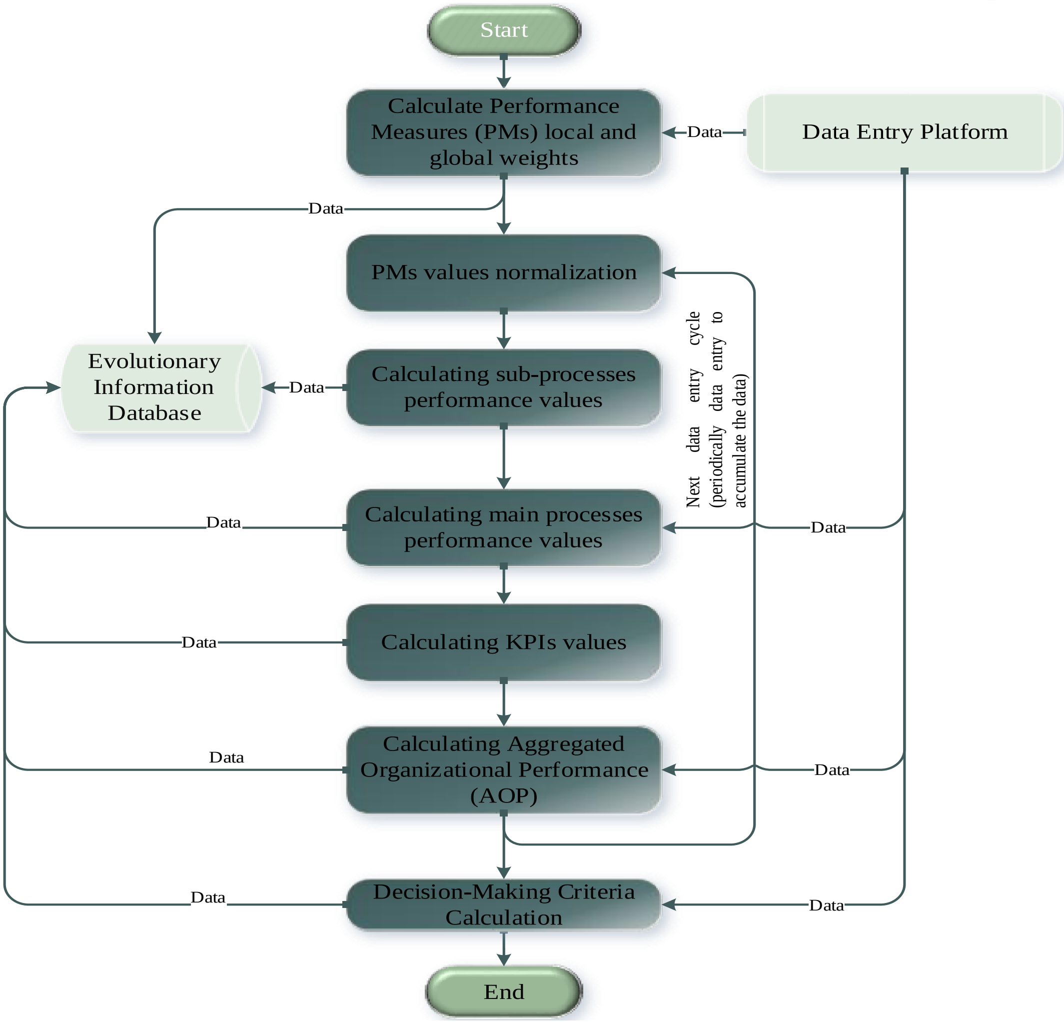

Figure (4): Computation process flow.

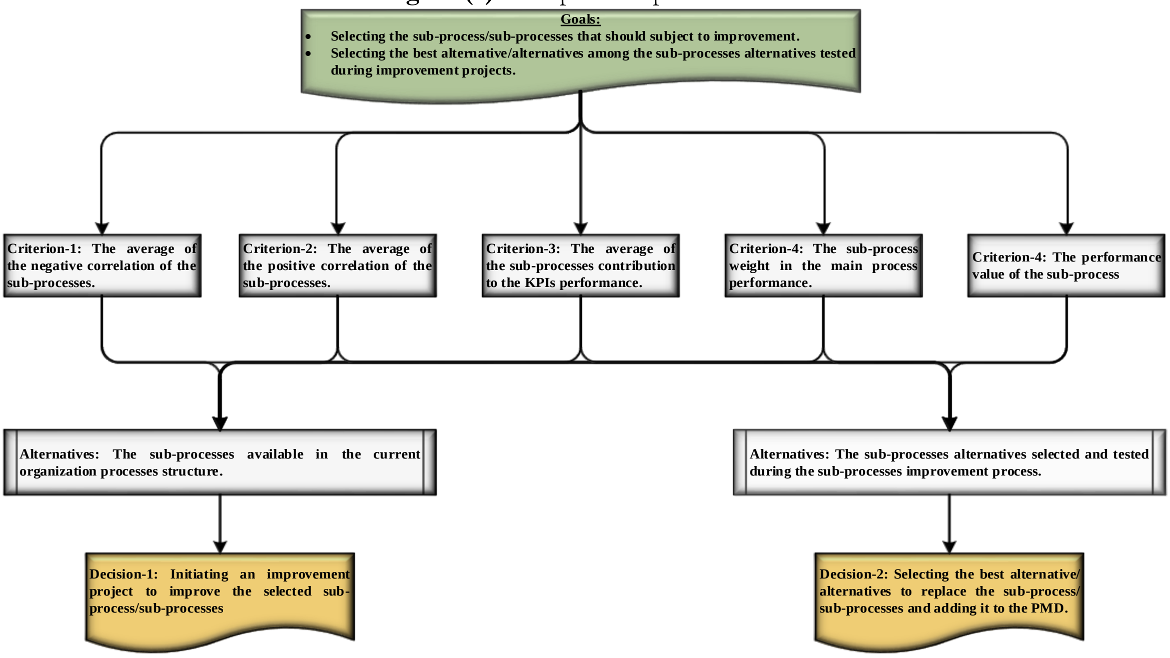

Figure (5): Hierarchy of the decision-making process.

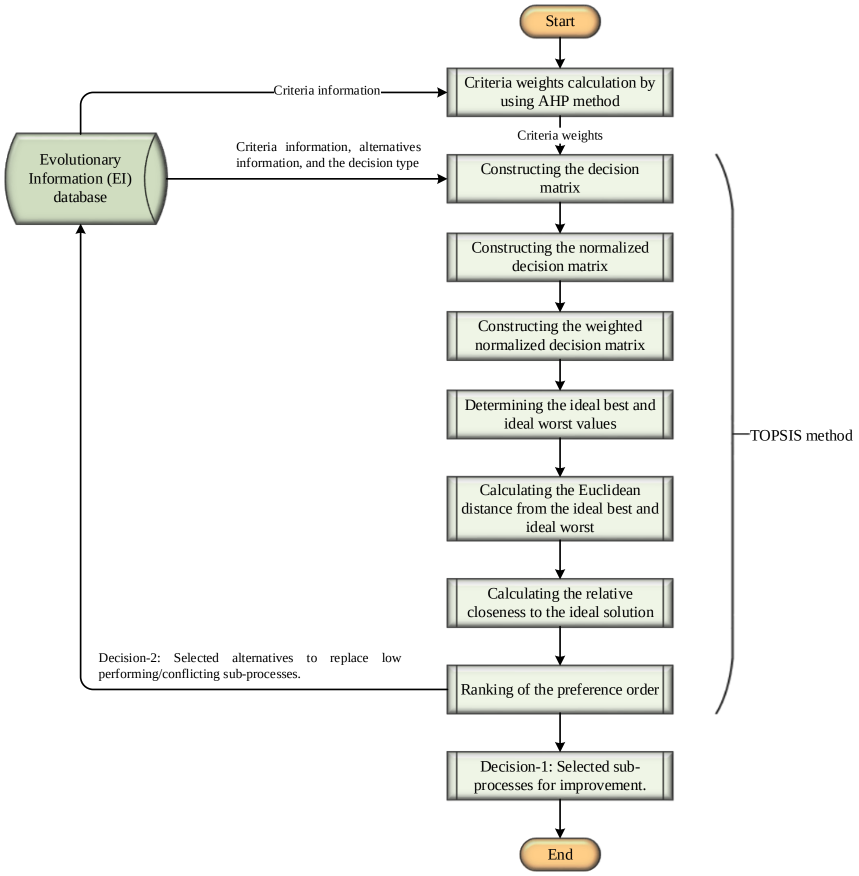

Figure (6): Decision-Making Tool (DMT) process flow.

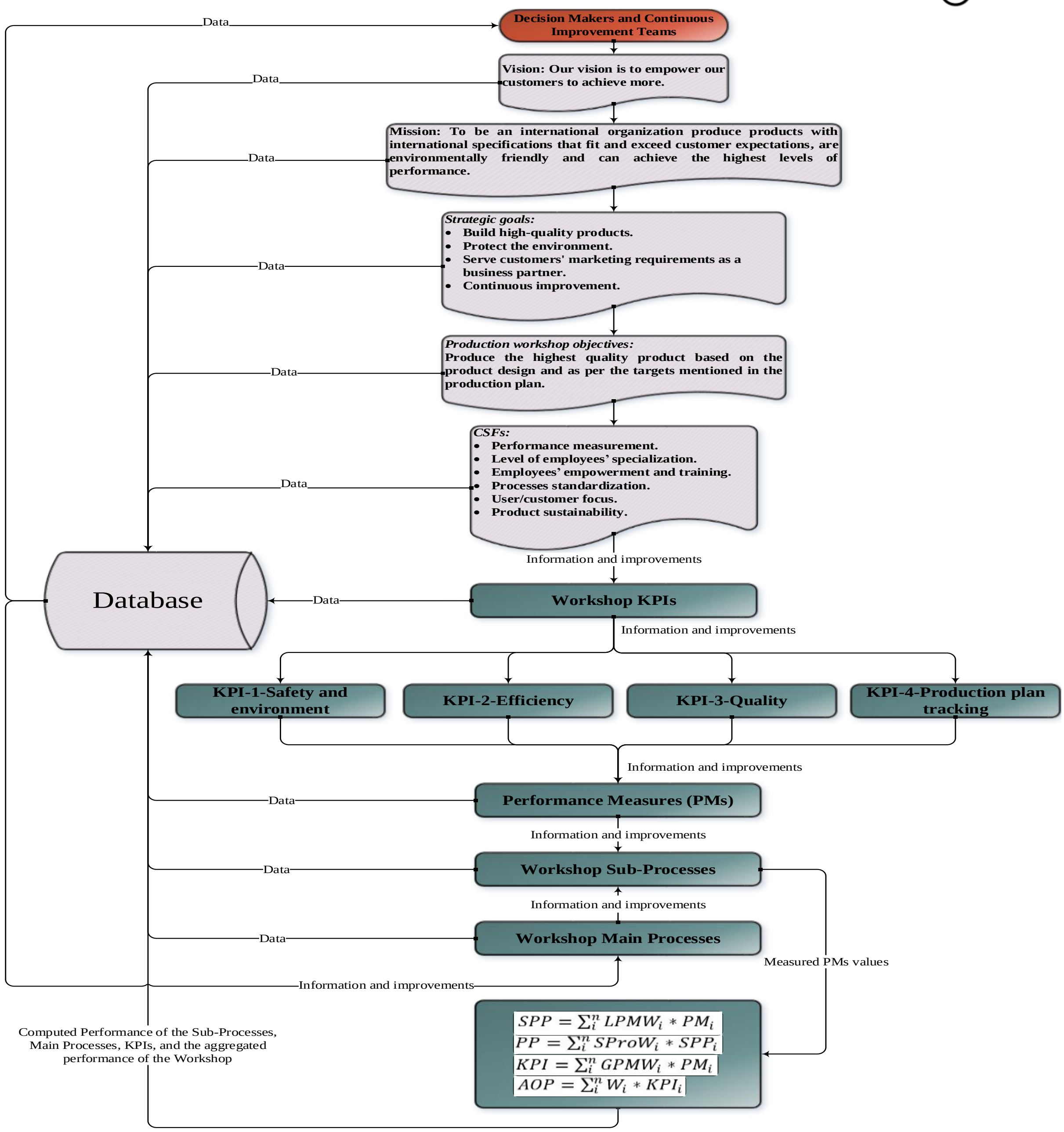

Figure (7): Simplified presentation of workshop GI V-DNA

The sub-processes and the KPIs' performance were computed based on the normalized PMs' values. Therefore, the dashboard helps decision-makers identify strengths and weaknesses in the low-performing areas/processes and the highly performing areas/processes by analyzing the PMs used to compute these areas/processes' performance. Exploring the PMs helps decision-makers identify the root causes of the low performance and the best practices in the areas/processes that showed a high performance from the measured PMs values. The proposed PMD showed that the performance values were computed based on the many PMs categories. Such a process clarifies that the achieved performance levels are balanced performance, i.e., it considers all performance areas, not merely high performance due to high productivity or financial revenues.

The correlation dashboard helps decision-makers see how the KPIs and the sub-processes correlate to each other and if any negative correlation exists between the KPIs or the sub-processes. The negative correlation indicates that increasing the performance in one of the KPIs or the sup-processes that negatively correlated with others will negatively impact the performance of the other KPIs or the sup-processes. Therefore, the decision-makers may need to work on the negative correlation areas to avoid it or monitor the processes to ensure having balanced performance, i.e., minimize the negative impact.

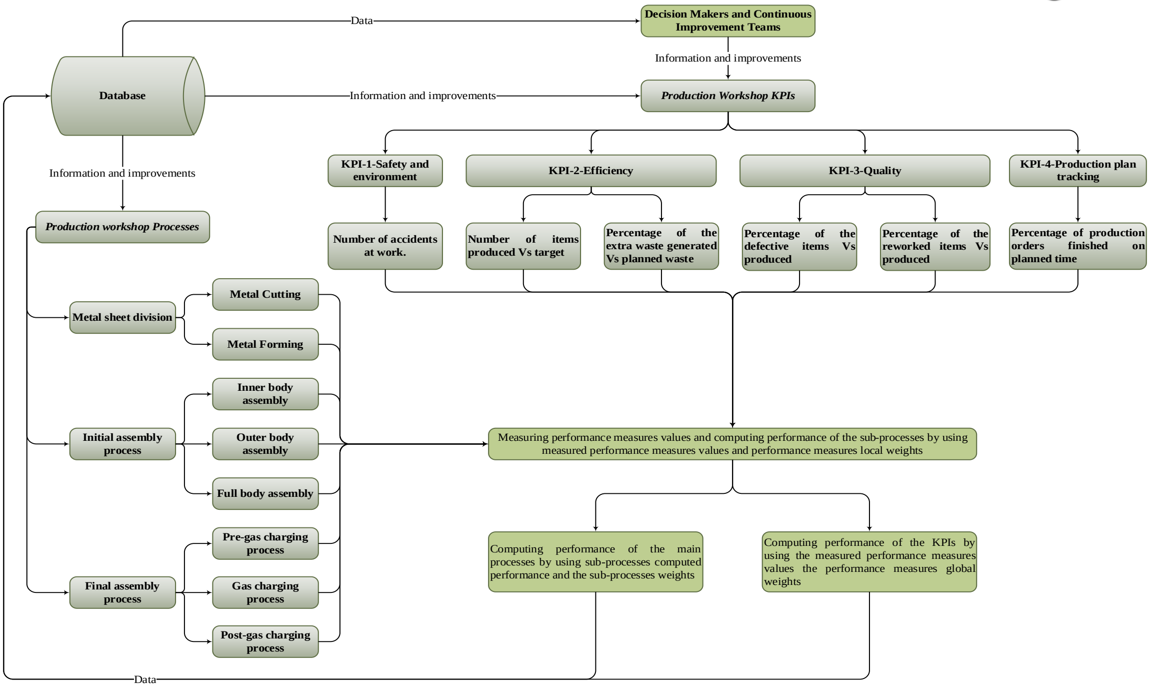

Figure (8): GI V-DNA of all processes in the production workshop.

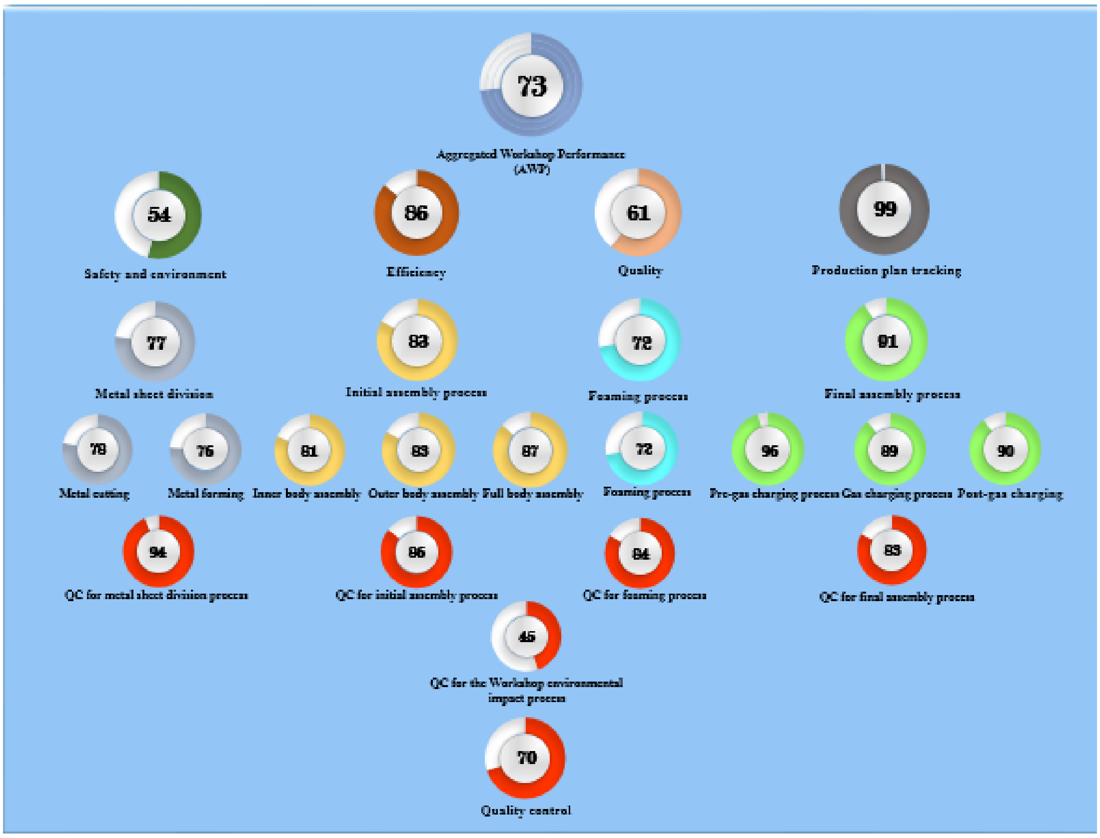

Figure (9): GI dashboard of the production workshop.

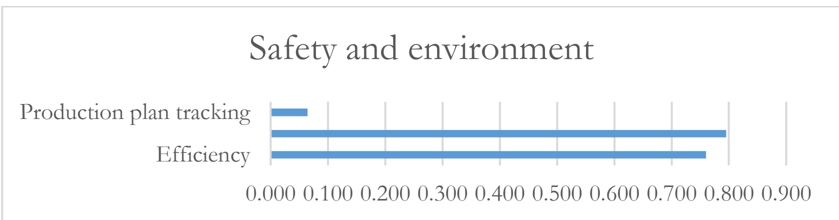

Figure (10): GI Dashboard-Sample of the KPIs correlation.

Figure (9 shows that the Aggregated Workshop Performance (AWP) was (73%). Based on the analysis conducted on the KPIs and the PMs, the reason behind this value was the low workshop performance in the safety and environment KPI and quality KPI despite that workshop was highly productive in terms of the production plan tracking KPI and achieved good performance in the efficiency KPI. These facts showed the PMS's usefulness in providing proper guidance to the decision-makers by providing a holistic view of the workshop performance areas instead of focusing on workshop productivity or efficiency. Therefore, the decision-makers need to identify the root causes, eliminate them, and improve these areas as primary improvement opportunities to improve the sub-processes, safety, environment KPI, and workshop performance.

As shown in Figure (11, the GI dashboard also shows the correlation between the sub-processes. All sub-processes in the workshop are positively correlated, which means increased productivity in one sub-processes will positively impact the other processes. However, the strength of the relationship is different from one sub-process to another. Hence, a conclusion can be made that no sub-processes need to be replaced because of the other sub-processes' negative impact. However, the major improvement opportunities, i.e., which sub-processes need to be improved, will be decided using the DMT. Therefore, the PMD is valuable and effective for identifying improvement opportunities.

4.4.4.3 DMT Amendment and Implementation

The first step of implementing the DMT was computing the weight of the decision-making criteria. The criteria weights were calculated using the DMT-AHP template. All sub-processes in the workshop were analyzed, and they have no negative correlation. Therefore, the weight of this criterion will be zero. So, the criteria used in the customized DMT will be the average of the positive correlation of the sub-processes, the average of the sub-processes' contribution to the KPIs performance, the sub-process weight in the main process performance, and the computed sub-process performance value.

The criteria weights were used in the second part of the DMT (DMT-TOPSIS) to select the sub-processes with the lowest performance to improve them. The results of running the DMT are shown in

Table (5. The first five sub-processes which may be selected as potential improvement opportunities include (1) QC for the workshop environmental impact process, (2) metal forming, (3) QC for the final assembly process, (4) foaming process, and (5) metal cutting sub-processes. These processes were selected because of their low-performance values. Such conclusions match the previous section's findings and confirm the PMD and DMT's usefulness. However, the final decision to choose which processes to improve and how they will be improved depends on the organization's management decision.

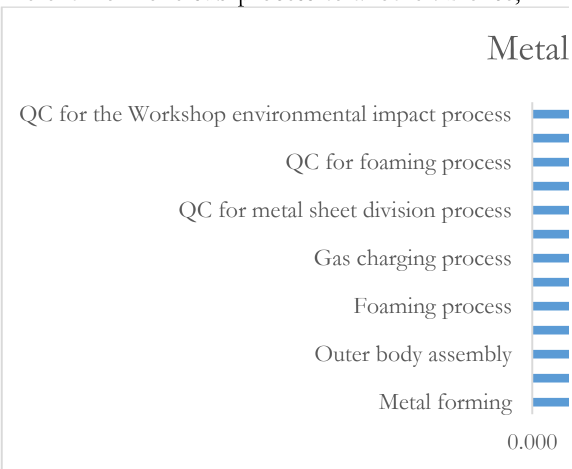

Figure (11): GI Dashboard-Sample of the sub-processes correlation.

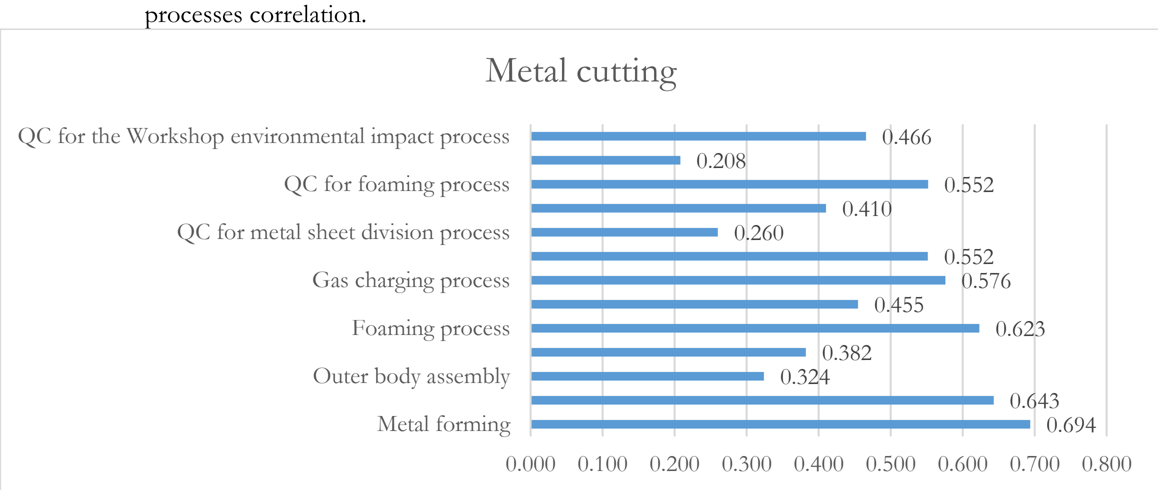

Figure (11): GI Dashboard-Sample of the sub-processes correlation.

Table (5): Ranking of the sub-processes in the production workshop.

Sub-Processes	Euclidean distance from	Euclidean distance from	Computed Performance	Rank

	the ideal best	the ideal worst		
Metal cutting	0.0501012	0.07551	0.6012	5
Metal forming	0.0530928	0.07219	0.5762	2
Inner body assembly	0.0423706	0.08433	0.6656	11
Outer body assembly	0.0495269	0.08466	0.6309	9
Full body assembly	0.0531745	0.09083	0.6307	8
Foaming process	0.0525884	0.07654	0.5928	4
Pre-gas charging process	0.0416094	0.11116	0.7276	13
Gas charging process	0.0333335	0.09940	0.7489	14
Post-gas charging	0.0498788	0.09812	0.6630	10
QC for the metal sheet division process	0.0452925	0.10701	0.7026	12
QC for the initial assembly process	0.0546099	0.08908	0.6200	7
QC for the foaming process	0.0522592	0.08486	0.6189	6
QC for the final assembly process	0.0586942	0.08240	0.5840	3
QC for the Workshop environmental impact process	0.1148756	0.02498	0.1786	1

4.4.5 Continuous Improvement Stage

The implementation results showed that the PMD provides a holistic view of the OP. It gives the decision-makers a visual presentation of the organization's performance on all levels, facilitates their mission of identifying the low-performing areas/processes and highly performing areas/processes, and helps them to identify the strengths and weaknesses in the low-performing areas/processes and the highly-performing areas/processes by analyzing the PMs used to compute these areas/processes' performance.

The DMT supports the conclusions that PMD provides and assists the decision-makers in identifying improvement opportunities in a systematic and structured approach. Hence, the developed PMD and the DMT are efficient and effective tools for monitoring and managing OP. The continuous improvement efforts will continue by applying the developed PMD and the DMT in other company departments, factories, and organizations from different sectors.

5 Focus Group

Four academic professors have been selected as a focus group to evaluate the results of the V-DNA and PMS (PMD and DMT) implementation and validate the proposed PMS. The proposed V-DNA concept and the PMS (PMD and DMT) were shared with the focus group members. In addition, a comparison between the previously used KPIs in the production workshop and the newly proposed PMS was shared with the focus group members.

The comparison results won't be shared because of the information confidentiality. The focus group members were requested to review and evaluate the proposed V-DNA concept and the PMS based on the features and elements of the robust PMSs presented in this research. Then, the focus group members were asked to check the shared comparison results and give feedback. The following points were highlighted during the discussion and as a result of the review process:

1. Focus group members discussed the proposed V-DNA structure and believe it is valid. They think it represents a novel idea of creating a knowledge-based database that explains the relationships between all organization's processes horizontally and vertically. It can store and recall the accumulated knowledge of all previous experiences and use it to support the decision-making process. However, the concept is in its infancy and needs more research in the future, especially for solving the V-DNA structure complexity when the V-DNA of the organization level needs to be generated. The comment was considered and will be included in future research agendas.

2. Academic experts believe that the proposed PMS is valid and scientifically robust and fulfill the required features and elements of a robust PMS. However, they recommended that, in future research, the PMD and DMT need to be tested at the company levels. Then, it may be generalized by applying it to other organizations from different business sectors. This recommendation was taken into consideration and added to the future research agenda.

3. The structure of the PMD, the hierarchy of the decision-making process, the decision-making criteria, and the decision-making process flow are logical. They can be a helpful guide for researchers and practitioners to construct the PMS for their organizations. However, the individual features of each organization should be considered.

4. The focus group members reviewed the comparison of the production workshop PMS before and after applying the proposed PMS. They have concluded that:

a. The set of the previous KPIs can indicate the factory and workshop's financial performance, productivity, and employees' performance. However, it doesn't reflect the real performance because it measures workshop performance without explaining the performance of each process. Therefore, the decision-makers cannot decide which process is low performing, why these processes' performance is low, and what their impact is on other processes.

b. On the other hand, the proposed PMS (PMD and DMT) measures the performance on the process level based on a set of PMs and checks the impact of the measured performance of each process on the other processes horizontally and vertically, on the KPIs and on the AOP. Therefore, the measured AOP and KPIs can be justified, and the decision-makers can explain the root cause of the high or low performance, why it is happening, and its impact on other processes. Hence, the decisions on the improvement projects can be taken based on quantified evidence and using a systematic methodology, especially with the proposed DMT.

6 Results and Discussion

The purpose of this section is to discuss the research results. Three research objectives were derived to fulfill the aim of the research. The literature analysis revealed the identification of the features and elements of the robust PMSs, which fulfill the first research objective.

Based on the archival literature analysis outcomes, the authors proposed an organizational V-DNA structure, the mathematical structure of the PMS, and the DMT for the PMS. The proposed V-DNA in the current research only represents one layer of the organization's business model, representing the linkage between its vision, mission, goals, objectives, CSFs, and the PMS elements, including AOP, KPIs, and PMs. It is expected that the complete representation of the organizational V-DNA may consist of other layers of its business model, such as the ethical side of the organization's business, human factors, and any other tangible and intangible factors. Therefore, future efforts will expand our understanding of the V-DNA concept and extend it to all other layers of its business model.

Regarding the PMD, it has been proved that the PMD should be constructed based on the organization's vision, mission, goals, strategy, CSFs, KPIs, PMs, and the processes which match the V-DNA structure. Therefore, any organization that wants to use the PMD template should construct its V-DNA and use it to modify the PMD template to fit its V-DNA structure. The structure of the PMD makes it smart and dynamic and can respond to any immediate changes in the organization processes structure, KPIs details, or PMs details. Visualizing the performance scores on all levels provides quick and straightforward feedback. Hence, the PMD has all features of a successful dashboard.

Regarding the DMT, The AHP and TOPSIS methods were used to construct the DMT. The approach used to select the decision-making criteria and build the decision-making process flow makes it generic. It can be implemented in other organizations rather than those targeted in the current research. It considers crucial business areas, considers the connections and the correlations between the processes, and focuses on the areas that will result in selecting the important improvement opportunities or the best-proposed solutions rather than focusing on isolated business aspects.

The designed V-DNA and the PMS (PMD and DMT) were amended and implemented in a production workshop at the headquarters of the international cold merchandizing equipment manufacturing company. The workshop is located in the UAE. The focus group discussion revealed that the V-DNA concept is applicable and can be an essential information source. The V-DNA represents an experience-based knowledge structure that systematically stores and reuses historical information to facilitate decision-making.

Focus group members found that applying the PMS (PMD and DMT) to monitor, analyze, and manage workshop performance was successful. The dashboard proved an efficient and effective tool that assists the decision-makers in having a complete picture of the workshop performance. By using the DMT, the decision-makers were able to evaluate all sub-processes and rank them based on the values and weights of the decision-making criteria and highlight the areas that need improvement. The decision-makers directly identified the low-performing and highly-performing KPIs/processes/sub-processes and identified the root causes of low and high performance.

The discussion elements in the above paragraphs fulfilled the second and third research objectives. Hence, the research goal is achieved. However, future work should focus on implementing the proposed PMS and V-DNA concepts at company level. Moreover, the comments received from the focus group are considered and will be included in the future research agenda.

7 Research Implications and Limitations

The academic implications of the research can be seen in the possibility of using the proposed V-DNA and the PMS to conduct future research in many organizational levels and business sectors. The researchers can use the proposed generic templates and test them in organizations of different sizes and sectors to check their applicability and revise the proposed templates' structures based on implementation results. Moreover, researchers can propose other layers of the organizational V-DNA.

The practical and managerial implications of the V-DNA and the PMS are clear because they present valuable tools to facilitate the organization's mission in monitoring, analyzing, and managing the OP effectively. The managers will see how each KPI, PM, process, and sub-process performs and how the organizational elements are correlated based on the V-DNA structure. Therefore, they can identify the areas that need improvement and initiate improvement projects using the systematic analysis available in the DMT.

The current research is limited to constructing the V-DNA structure and the PMS at the organizational level. However, because of the complexity of the V-DNA structure, the proposed structure in the current research is only one layer of the V-DNA which covers only the processes structure and the historical records related to them. Future work will focus on developing other layers of the V-DNA and linking them to the first layer.

8 Conclusions

This research aims to develop and validate a smart PMS. The PMS will create a foundation for PMSs that will be used by organizations in the digital era. The research resulted in proposing a generic PMS based on the features and elements of the robust PMSs. A systematic literature review process was conducted to extract the features and elements of the robust PMSs from the literature. The PMS consisted of PMD and DMT, which were developed based on a novel V-DNA concept. The V-DNA was constructed based on the organization's processes structure and other elements of the robust PMSs. The proposed V-DNA structure consists of the GI and the EI of vision, mission, goals, CSFs, organization processes structure, sub-processes, PMs, KPIs, AOP, and the relationships between these elements.

The proposed V-DNA concept will help us understand how any change (positive or negative) in one area can impact other levels, systems, processes, and sub-processes. The proposed V-DNA in the current research only represents one layer of the organization's business model, representing the linkage between its vision, mission, goals, objectives, CSFs, and the PMS elements, including AOP, KPIs, and PMs. It is expected that the complete representation of the organizational V-DNA may consist of other layers of its business model, such as the ethical side of the organization's business, human factors, and any other tangible and intangible factors. Therefore, future efforts will expand our understanding of the V-DNA concept and extend it to all other layers of its business model.

The PMD was constructed based on the features and elements of the robust PMSs and encompassed a group of platforms and databases, which are interconnected based on a set of mathematical equations extracted from high-quality scientific references. The AHP and TOPSIS methods were used to build the generic DMT template. Using the V-DNA concept showed that the V-DNA concept is applicable and can be an essential information source. Applying the PMD and the DMT to monitor, analyze, and manage workshop performance was successful. The PMD proved a useful tool that can provide a holistic view of the workshop performance areas instead of focusing on isolated business aspects such as workshop productivity or efficiency. The decision-makers directly identified the low-performing and highly performing KPIs/processes/sub-processes and identified the root causes of low and high performance. The DMT proved a useful tool. The decision-makers could evaluate all sub-processes and rank them based on the values and weights of the decision-making criteria, highlighting the areas that need improvement.

Future research efforts will focus on solving the V-DNA structure complexity and proposing other layers of the V-DNA. Another future research goal is to apply the PMD and the DMT at the company levels and branches. Then, it may be generalized by using it in other organizations from different business sectors.

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