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Software & Data Engineering

Intelligence without Data

Evaluation of Software using Formal Methods

Highlights

Robustness Algorithms for the Airport Gate

SDWAN Technology Evaluation and Implementation

Discovering Thoughts, Inventing Future

VOLUME 20 ISSUE 1 VERSION 1.0

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SDWAN (Software Defined-WAN) Technology Evaluation and Implementation

By Anshuman Awasthi

Abstract- Many organizations are struggling to provide high bandwidth and reliable internet connectivity at their branch offices and business locations and getting the most out of their operational expense. The need for internet connectivity at any branch offices and business locations is no longer a luxury but is a necessity. Let us try to understand how to replace the traditional MPLS network with the new SDWAN (Software - Defined- Wide Area Network) technology. We will try to understand why it is essential to implement the latest technology instead of investing in the existing MPLS (Multi- Protocol label switching) by taking an example of a retail organization. We also have a look at how to evaluate the product by using some metrics and how different teams are involved during different phases of the project.

Keywords: network engineering, SDWAN implementation, ROI analysis, technical project management, MPLS replacement.

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SDWAN (Software Defined-WAN) Technology Evaluation and Implementation

Anshuman Awasthi

Abstract- **Many organizations are struggling to provide high bandwidth and reliable internet connectivity at their branch offices and business locations and getting the most out of their operational expense. The need for internet connectivity at any branch offices and business locations is no longer a luxury but is a necessity. Let us try to understand how to replace the traditional MPLS network with the new SDWAN (Software - Defined- Wide Area Network) technology. We will try to understand why it is essential to implement the latest technology instead of investing in the existing MPLS (Multi-Protocol label switching) by taking an example of a retail organization. We also have a look at how to evaluate the product by using some metrics and how different teams are involved during different phases of the project.**

Keywords: network engineering, SDWAN implementation, ROI analysis, technical project management, MPLS replacement.

Methods: This project/research was performed using the abilities of Software Defined Network Technology and options available in MPLS (Multi-Protocol Label Switching). The Technical Project management principles were adopted as per PMI (Project Management Institute) waterfall methodology.

Results/Conclusion: SDWAN technology provides an adequate replacement of the MPLS network connection for providing WAN connectivity for our office locations. It is essential to follow a documented process for appropriate vendor selection based on the available features and other listed attributes in the article. To increase the chances of the success in the implementation, it is essential to perform a POC (Proof of Concept) in a controlled environment and validate results. SDWAN provides better network performance and improves reliability as the links operate in active-active function.

I. Introduction

A retailer has to perform several transactions in a business location, and there is a need for a reliable high-bandwidth internet circuit. In the absence of a high-speed internet connection, many sites may report slow internet performance as they may be running on a single high-cost low-bandwidth internet connection. This initiative targets to deploy SDWAN technology at all the business locations. The IT Network Engineering team of an organization can lead this initiative, but as this is a cross-functional project. It will need help from different groups like IT Operations for Server and Storage requirements, Business Support for coordination with Business Associates, Network Administrator, and Onsite Tech support team. They will be responsible for device installation at all galleries. In addition to these stakeholders, we need to have a dedicated Project Manager (PM) to monitor the project's overall progress, who will coordinate with COO for any budgetary issues and with VP –Infrastructure to allocate necessary organizational resources. The designated PM will work closely with Director Project Management Office to ensure the scheduled tasks for this project do not interfere with the plans in other areas of the business as the company has multiple projects in progress at the same time. This Project has four phases Design, Initial Implementation, Rollout, and Project Closure. We will estimate the average internet bandwidth upgrade and percentage increase in network and hardware reliability by reviewing the incident data post-upgrade to calculate the overall success of the project.

a) Cause

Below factors are contributing to the poor network performance and causing unreliable network connection at several business locations.

- Most of the business locations have a high-cost low-bandwidth Private WAN (Wide Area Network) circuit. This circuit is very reliable but does not solve the increasing demand for high-bandwidth.
- Many locations are just operating on a single Private WAN circuit. Very few locations have a reliable secondary network connection.
- The business locations with dual circuits cannot utilize bandwidths effectively, as due to technical limitations, they are operating on Active/Passive mode. (Only one connection can be operational at one time).

b) Proposed Solution

The existing technology using traditional network architecture is undoubtedly unable to provide a solution that can solve our needs and still be affordable. The time has come to explore the capabilities of the SDWAN (Software - Defined Wide Area Network) solution. According to Wikipedia (n.d.), an SD-WAN simplifies the management and operation of a WAN by decoupling (separating) the networking hardware from its control mechanism. This concept is similar to how

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software-defined networking implements virtualization technology to improve data center management and operation.

An essential application of SD-WAN is to allow companies to build higher-performance WANs using lower-cost and commercially available Internet access, enabling businesses to partially or entirely replace more expensive private WAN connection technologies such as MPLS.

II. Evaluation

a) Evaluation Approach

If the organization decides to implement SDWAN technology at all the business locations to improve the network performance and reliability, the IT Network Team can estimate the new bandwidth requirement using Solarwinds NPM (Network Performance Monitor) tool. The team should monitorall the interfaces of network devices at business locations and gather data about current usage; we can make use of this to estimate the required bandwidth of new circuits at each location.

The needs, as mentioned earlier from the new technology, will help to decide on the metrics to evaluate the project's success. In addition to the network performance parameters, we can also add some service and operational improvement data points to improve the overall experience of the employees concerning this project. The inclusion of service improvement metrics in the project's success will also ensure the vendors involved in the project to provide quality service since we will evaluate their performance as a part of the project's success.

b) Quality Assurance Criteria (Metrics)

We can use below Metrics as a reference to measure the proposed and actual outcomes of the project.

Evaluations Area	Proposed %	Actual %	Business Feedback
Internet Bandwidth Upgrade			
Network Reliability			
Hardware Reliability			
Ease of Installation			
Ease of Access			
Network Management			
Security Policies Management			
Vendor Support			

We can evaluate the network performance using a tool that is an industry leader in performing a speed test called OOKLA. To measure the overall network performance and compare the pre and post-installation results, we can use Solarwinds NPM (Network Performance Monitor). To measure incident ticket count and ease of administration using the incident resolution time matrix, we can use any ticketing tool like Service Now, one of the most popular Cloud-based ticketing systems in the industry today. We should only select an SDWAN partner once theyprovide supporting documentation that their product has passed the necessary security and health safety tests.The organization can also perform a vulnerability test once the product is installedat its first location to ensure there are no new vulnerabilities discovered in the network.

c) Solution Testing

To perform extensive testing with the new SDWAN solution provided by the vendor, the project team needs to work on a test location where they can replace the old router with the latest hardware and perform connectivity tests. The SDWAN technology partner can providean appliance for the testing purpose; the organizationIT team can use the new hardware with the old network switch if the experts from theSDWAN team confirms that there will be no compatibility issues.

Please refer below the list of activities and observations as a reference that we need to execute every day to test the SDWAN hardware and software. The list of activities and the number of days required for testing are as per the use case.

Location to be tested: Pleasanton (PL) ,CA
Person in-charge for testing:Name1,Name2
Thursday 1st Oct Activity
Day1 -Activity
Created new Policy with Standard format and added ABC.com, Google, Yahoo,Linked In to choose all Network Paths
Switched On SDWAN-Observed 8 Ping Loss

From Pleasanton to Data Center average response time is 7ms
Turned on SDWAN at PL-Took around 2mins for steady response
Disconnected MPLS from providers end
Day1 -Observations
First -Internet and Datacenter Sites were reachable. MPLS sites were not reachable.
Second-Internet went down.Data Center sites were reachable
Internet went down and didn't come up
All sites went down
Connected MPLS Router back-connectivity is restored
Disconnected MPLS from WAN port for SDWAN
First, only connectivity to Datacenter was up
Then connectivity to all sites went down
Connected MPLS back to original state-all sites were online
Observation-Traffic is going to a blackhole- Needs investigation

Day 2 -Activity
The modified LinkedIn policy only to use MPLS and Internet(No Internet VPN)
Added 8.8.8.8 as DNS in SDWAN in PL as DNS along with Infoblox as the third option
Disconnect Router WAN connection
Day 2 -Observations
Linked was working but Yahoo and YouTube didn't work-Cannot ping to any internet sites
YouTube and Gmail was added to use the Direct Internet path and not to use Internet VPN
YouTube is working very slow
Direct Internet websites response is very slow and not reliable
Observation- Needs more investigation on high latency in direct internet response
Connected SDWAN appliance back
We switched back to original policies where we started

Day 3 -Activity
Validate All policies in Pleasanton
Add floating static Routes in on Rack 7 and Rack 6 Edge switches at Data Center for Pleasanton office
Change all applications listed in SDWAN policies to use a dual path
1. Organization Websites- All Routes
2. Symantec- Internet VPN +MPLS
3. Google- All Routes
4. YouTube- All Routes
5. LinkedIn- All Routes
6. Casper (Software management on MACs)- Internet VPN +MPLS
7. Yahoo Mail- All Routes
8. Google Hangout- All Routes
Start continuous ping to few websites
Disconnect Internet Circuit from SDWAN (Observe for any blips)

Connect Internet Circuit
Start Continues ping to few websites
Disconnect MPLS Circuit from SDWAN (Observe for any blips)
Connect MPLS circuit to SDWAN (bypass Cisco Router)
Perform Trace route to Data Center,Internet Sites,P2P(Point to Point), and MPLS sites
Day 3 -Observations
Check Core Switch in Data Center for new routes
Check MPLS Router in Data Center for new routes
Is MPLS working in Pleasanton -Yes

Day 4 - Activity
Connect MPLS back to Verizon Box
We had intermittent connectivity to complete connectivity loss
Tried rebooting the Verizon device
Tried rebooting MPLS router
Disconnect internet circuit from SDWAN
Day 4 -Observations
Stable connection
Able to browse to yahoo, google

Test Cases

Day 5-Activity
Upgrade Image on PleasantonSDWAN to 0.16.4
Internet +MPLS (MPLS is already connected just connect Internet)
Day 5 -Observations
We had intermittent connectivity to complete connectivity loss to internet websites

Day 6-Activity
Upgraded to version 0.185 on Hub and SDWAN
Connected Internet Circuit
Day 6 -Observations
Stable connection
Able to browse to yahoo, google

After multiple days of testing and running different scenarios, we can reach a stable image and network architecture.

d) Acceptance Criteria and Evaluation Framework

The Project Teamcan make a list of the abilities for the product acceptance criteria. It will also help to measure performance attributes and operational improvements.

Evaluations Area
Internet Bandwidth Upgrade
Network Reliability
Hardware Reliability
Ease of Installation
Ease of Access
Network Management
Security Policies Management
Vendor Support

The Project Manager, along with the help of Leadership and other teams, can perform the Cost-Benefit Analysis. Please refer below Cost Analysis for developing, installing, and supporting an SDWAN appliance at a business location. To justify the investment (project cost), we have also put together some data on how much time we are spending on the support of maintenance of existing network infrastructure and incidents that are occurring due to the bandwidth and technology limitations. It is essential to make a note of the financial loss we have to suffer in case of an internet outage at a business location.

Please refer below Cost Analysis table as a reference.

Cost -Benefit Analysis of using SDWAN as Internet Appliance at Locations	
Projects Costs per Location	**Amount**
Datacenter Hardware	
Datacenter Hub -Product Design and Development	--
Site Hardware	--
Software & Licenses	--
Support (Included in License)	--
Internal - Labor ($75/ hour) -Installation 2 hour per location	--
External -Labor ($125/ hour)-Installation 4 hour per location	--
Internet Connection 1 -Monthly Recurring Charge per location	--
Internet Connection 2--Monthly Recurring Charge per location	--
Total Capital Expense for each Location (Only First Year)	--
Total Operational Expense for each Location	--
Current Costs (Project Cost Justification)	
Current Site Hardware Support	--
Current Datacenter Hardware Support & Maintenance	--
Internal - Labor ($75/ hr) - To solve Incidents	--
External -Labor ($125/ hr) - For Technician	--
Internet Connection 1	--
Loss in revenue due to internet outage (per hour)	
Large locations	--
Small Locations	--
Total Operational Expense	--
Revenue Loss per hour for each location (Outages-Due to old Technology/Hardware)	--

It can become very clear from the above Cost-Benefit Analysis that the organizations are spending considerable amounts in supporting the existing technology and not getting any benefits in return. It is advisable to invest in the new technology and avoid these outages so that we can run our business smoothly. The modern technology architecture is centrally managed through a cloud-based controller and needs minimum operational expenditure post implementation.

In addition to the above-mentioned acceptance criteria, which includes Cost-Benefit analysis, hardware/ technology performance the project team should involve the legal team to create an MSA (Master Service Agreement) which includes some pre-checks to ensure the vendor is following all the environmental and legal obligations like the validation of their W9 form, tax returns. Once we got a go-ahead from all the different teams, the project team collectivity decided a partner to work.

III. Project Review

a) Phases & Milestones

The SDWAN implementation project has four phases, with below listed main milestones in each group.

First Phase: SDWAN Design

- Identify what SDWAN has to offer
- Research available SDWAN vendors
- Finalize an SDWAN Vendor
- Shortlist a vendor and perform a POC

This phase will lay the foundation stone for the project; the project team needs to be aware of the fact

that if they make a wrong decision at this stage or they miss on a critical test scenario to evaluate the product, it can take the whole project to the failure. The Project Manager needs to spend a lot of time with the technical Teams to document all the evaluation parameters to ensure we select the appropriate SDWAN technology partner. It is essential to make all the configuration changes in the test environment before we say that the technology is ready to be implemented in production. At the end of this,the team can select an SDWAN partner that provides relevant documentation to integrate the new technology into the existing enterprise network. The team should also evaluate their assumptions and carefully recorded various network performance parameters.

Second Phase: Initial Implementation

- Implement a solution in the first location and evaluate results
- Implement the solution in five more locations

The activities in this phase are essential before the team goes into the full rolloutphase, as it ishelpful to implement the solution on a smaller scale, collect feedback, and make final configuration changes. This phase will help the team to fine-tune their skills required in the rollout phase to implement the solution in multiple locations. The Network team should work with the onsite operations to install the SDWAN hardware in the first location. If the new technology andequipment's verification in the previous phase,there should be no big surprises. Still, there can bemany learnings that can help the team to prepare a precise playbook that should be followed by the technicians for the installation of the hardware in the other locations.

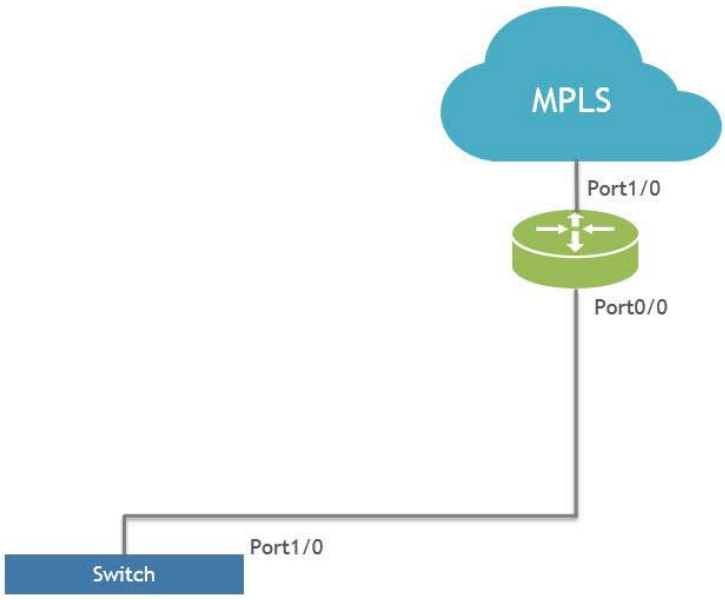
Third Phase: Rollout

- Implement the final solution in the remaining Business and Office locations
- Review results with the Operations team and Management
- Prepare Training and Documentation

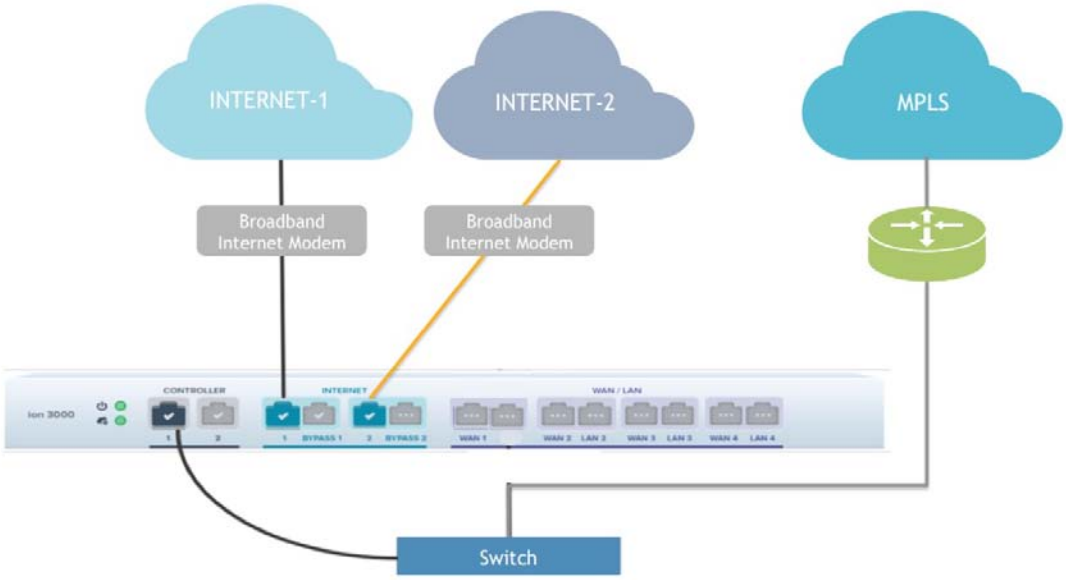
In thisstage, all hands on deck are required. The team should feel confident about the solution, as we have done enough testing during the earliertwo stages. The PM helped to coordinate all the scheduled tasks and allocate resources as per the plan. The Support Team should work with the Network Administrators and Onsite Tech for the installation and configuration of the SDWAN hardware. The project team can prepare a detailed playbook on what steps to follow along with the diagrams for the device installation and perform application testing.

Please refer below diagram for reference, showing steps for connecting SDWAN devices in a location.

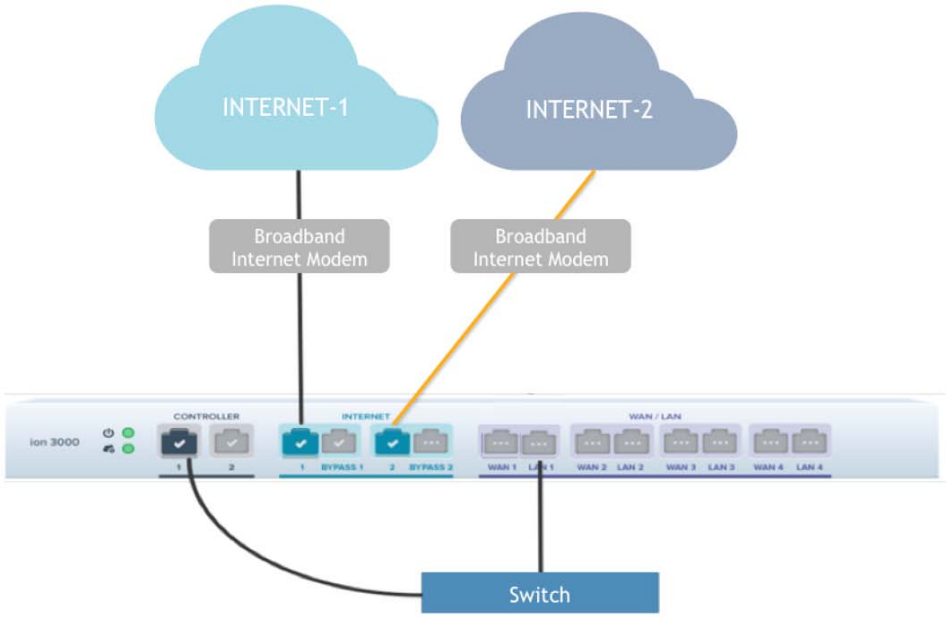
- Existing Setup



- Step 1- Connect controller port to switch



- Step 2- Move Router link to SDWAN appliance



The Project Team can prepare a detailed set of instructions for technicians on what equipment's/tools are required to perform the installation. Please refer toa sample of instructions.

The objective of this visit is to visit the business location and complete the Network Conversion to make Primary and MPLS Router/Failover on the new SDWAN device using the equipment on Day 1. You will work with the Network Team before making any cable move.

b) Equipment Needed by Tech

- Working computer with working NIC
- Cat5 Ethernet Cable
- Null Modem Cable (Console cable)
- Punch down tool
- Label Maker

c) Hardware to be Found Onsite

- Broadband Wireline Modem
- SDWAN Device
- Red, White, and Green patch cables

The Project team can create a list of tests to perform application testing post-installation. A sample of test instructions is mentioned below:

Once you have made the connection updates and the Network contact has confirmed the network is up, request the location Leader to follow below test plan:

- Test iPad to connect to Organization's Intranet website
- Test iPad to Gmail
- Test iPad to CNN.COM
- Test iPad for printing

- Test POS (Point of Sale) for printing
- Test POS for $ transactions-look for an item
- Test PC for Internet
- Test PC for printing
- Test wireless phone for an incoming and outgoing call

With the help of these installation details, along with the helpful diagrams and test instructions, the installation crew can perform installations successfully. The PM needs to schedule conference calls to review past installations so that we can learn from the mistakes and make necessary changes for future installs.

Fourth Phase: Project Closure

- Conduct Training for Operations and Support Team
- Handover to Operations
- Update Integrations with Incident Management Tool
- Prepare Project Closure Documentation

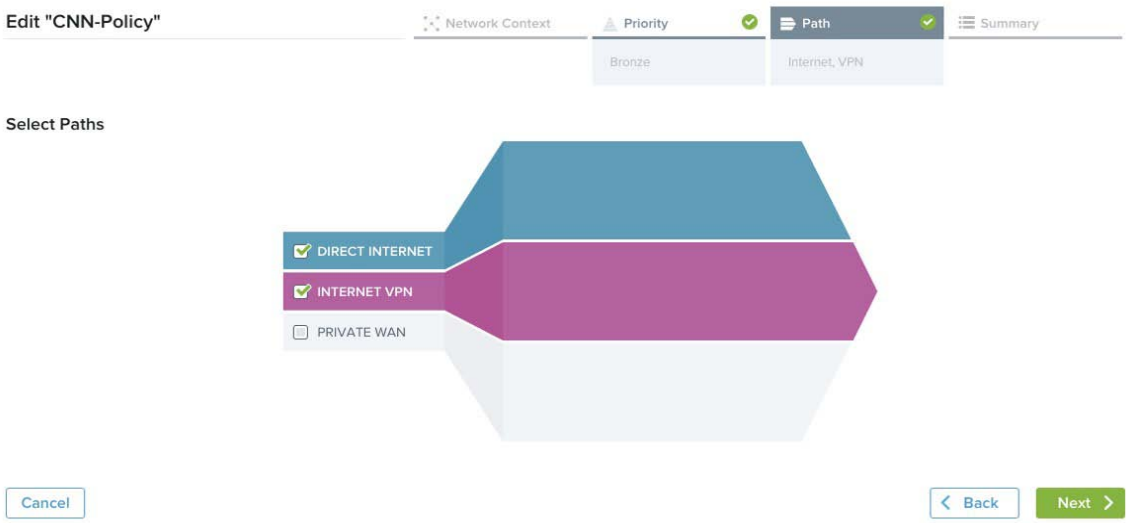
According to MOP (n.d.) Project closure activities ensure the recording project documents, archiving in organizational process assets, making final payments, releasing resources, and completing the project. Every project teaches lessons to the organization, whether it is a success, or it is a failure. So even after a project finishes, the documentation of this project will be helpful for completing the future projects successfully.

During this phase, the PM worked with the Project Technical team like Network and SDWAN partner to create documentation that includes the below details.

- How to support the new SDWAN technology
- How to perform daily administrative tasks
- How to troubleshoot any wireless network issues with SDWAN device.

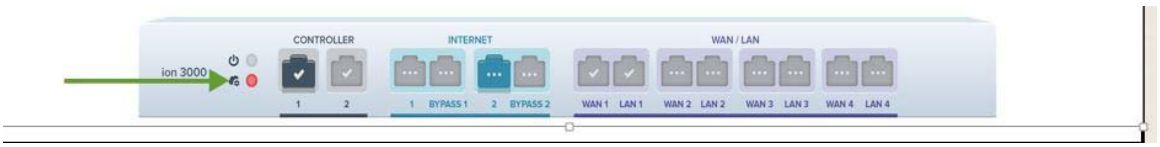
Please refer sample of instructions as a reference that can be created by the project team to handover to operations.

- Path Selection process



- How to check Device Status

Red indicates the device has no power:



Green indicates the device has power:

Solid color means configured and connected:

Not configured and No connection:

Ports configured but not connected:

The PM should schedule few trainings for the support team members. The technical team members who performed the actual implementation should lead the training sessions. It is due to the detailed support documents and the training workshop; the support team can gain the confidence to work on the new technology.

The PM needs to work with the IT Operations team to integrate the new technology with the existing enterprise applications. Once we have completed all the necessary administrative tasks, including paying the due invoices and reviewing actual time spent vs. time allocated, the PM should send a project closure report to the management and all the stakeholders involved.

Timeframe:

Please refer below chart to compare the planned vs. actual period as a reference. The team may encounter some initial challenges during the testing phase due to which they may have to extend the SDWAN design phase by sometime. As mentioned in the previous section, the team prepared very detailed installation instructions to expedite the installations. We have highlighted the estimated timeline in grey, and the actual time it took is done in red.

Duration	Week1	Week2	Week3	Week4	Week5	Week6	Week7
Phases							
SDWAN Design-Planned							
SDWAN Design-Actual							
Identify what SDWAN has to offer							
Research available SDWAN vendors							
Finalize a SDWAN Vendor							
Shortlist a vendor and perform a POC							
Initial Implementation-Planned							
Initial Implementation-Actual							
Implement solution in first location and evaluate results							
Implement solution in five more locations							
Roll out -Planned							
Roll out -Actual							
Implement final solution in remaining locations and outlet locations							
Review results with the Onsite operations team and Management							
Prepare Training and Documentation							

Project Closure-Planned							
Project Closure-Actual							
Conduct Training for Operations and Support Team							
Handover to Operations							
Update Integrations with Incident Management Tool							
Prepare Project Closure Documentation							

d) Dependencies

In this project, each phase can relate to other phases in sequence. Hence, the tasks associated with each phase also had a sequential relationship with each other (Dependent Tasks are highlighted in each phase in the timelines section). However, action items in the project closure phase were supposed to be carried out concurrently (Tasks in the project closure phase are not highlighted). The project team members should perform the tasks as per the plan.

e) Resources

Skills	Project Phases (Estimated hours)- Only for Reference			
	Project Initiation	Initial Implementation	Roll Out	Project Closure
Phase Duration	2 weeks	1 week	2-3 weeks	1-2 weeks
Project Manager	40	30	30	70
Network Architect	60	30	10	40
Network Administrator	20	50	200	50
Onsite Support	10	20	100	60
IT Operations	10	20	70	20
SDWAN Partner	30	20	100	50

f) Milestones

The project team can plan for below milestones based on the implementation strategy.

- Finalizing an SD-WAN vendor
- Finalizing the network design with the SD-WAN vendor
- Implementing SD-WAN technology in the initial pilot location
- Reviewing performance results with the project team and management
- Obtaining approval to proceed with the rollout
- Implementing SD-WAN technology in all the locations
- Handing over to operations

g) Deliverables (Hardware and Software)

- SD-WAN hardware installation in all office locations
- Dual direct internet access circuit installation at all locations
- Network policy configuration for SD-WAN software
- Security policy configuration for SD-WAN software

h) Implementation Plan for Documenting Deliverables

The project team planned to submit the below documentation as deliverables.

1. Non-disclosure agreements (NDAs) with various SD-WAN providers for technology review.
2. Master Service agreement (MSA) agreed with the SD-WAN partner.
3. Statement of works (SOW) agreed with the SD-WAN partner.
4. Detailed project plan.
5. Network architecture diagrams prepared, showing the SD-WAN in the production network.
6. Application integration documentation prepared.
7. An SD-WAN hardware installation guide produced.
8. Organizations network topology developed, including an SD-WAN network administration guide produced.
9. An SD-WAN Location support guide produced.

IV. Revisions made based on Formative Evaluation Results

The project team may need to perform some revision in their plan or test scenarios based on their observations or initial test results. Please refer below iterations as a reference.

Revision 1:

More test scenarios were included after initial testing of the SDWAN technology.

The Project Team selected an SDWAN partner based on the features available in their product and various other factors like ease of installation. During the SDWAN Design phase, when the team started to test the application in the existing enterprise network, the group encountered a few challenges, as the application did not work as expected. The Network Team worked extensively with the SDWAN technical team to figure out what changes are required in the existing network configuration to accommodate new technology. The PM and the professional team decided to include more test scenarios based on the experience.It will also help to ensure they do not encounter any challenges in the rollout stage as that will cause an interruption to the operations, and it may take the whole project in jeopardy. This revision helped the project in a big way, and the team decided to do a few more design changes in the network architecture before going to the next phase.

Revision 2:

Perform the rollout in two weeks instead of three.

It is imperative to implement the new technology as soon as possible, especially before any big holiday season, as that is when most of the sales happen. The team had taken some extra time during the SDWAN design phase,and PM realized that with the current plan, they would not be able to complete the project as per the schedule. The PM met with the Leadership Team,and they collectively decided to request Onsite Tech partner to allocate extra resources to perform multiple installations at the same time at different locations. The project team has already worked extensively to develop the installation playbook and application test instructions that helped the installation crew to install with only a few issues. Due to the expedited schedule that the project members decided,the team was able to complete the project on time.

V. Plan for Summative Evaluation

According to NIU (n.d.), Summative assessment takes place after the project has been completed and provides information and feedback that sums up the teaching and learning process. Summative evaluations are more product-oriented and assess the final output, whereas formative assessment focuses on the process of completing the product.

With the help of inputs received from various stakeholders, including leadership, technical, and operations, the project manager performed Summative Evaluation at the end of the project. The PM evaluated the project from various aspects as per below.

- Compare proposed Vs. Actual Deliverables
- Budget Allocated Vs. Actual Spent
- Resources Allocated Vs. Actual
- Timelines (Planned Vs. Actual)
- Significant challenges encountered in various phases
- Impact on operations due to project activities
- Return on Investment (ROI)
- Associates feedback

The PM has planned to use this data to conduct a lessons learned session along with the Leadership Team, which will help the organization carry out future projects more efficiently.

VI. Project Reports and Evaluation Results

The PM can plan to send reports and evaluation results to the below group of stakeholders.

First Stakeholder Group: Internal Technical Teams

This Stakeholder group is consists of two primary teams: IT Network and IT Operations

1. IT Network Engineering
2. Network architecture
3. Network administrators

Responsibility: IT network engineering

The organization's network engineering team should work closely with the SD-WAN technology partner to design the network; administrators will be responsible for the switch and appliance configurations. They will work as per the agreed implementation plan and scheduled tasks.

IT operations (server & storage)
Server administrator
Storage and backup administrator

Responsibility: IT operations

The IT operations team will provide the necessary computer storage for hosting the application in the data center. The server administrator will integrate the SD-WAN platform with other enterprise applications such as Okta for single sign-on or monitoring tools like Solar winds for alert monitoring purposes. The storage and backup administrator will provide the capacity for the servers and will be responsible for adding any servers to the backup policy.

Reports & Evaluation Results for this group:

The PM can plan to send below reports to this group using enterprise email.

- Daily Design reviews and architecture draft (in SDWAN design phase)
- Network Architecture
- Application integration documentation
- Product information
- Product Performance Matrix
- Project Plan
- Weekly Project Updates
- Resource utilization
- Project Closure

The PM will also schedule technical workshops with this group during the SDWAN design phase and weekly conference calls with all the stakeholders during the Initial implementation and Roll-out phase. The PMO (Project Management Office) will also create a common shared folder the enterprise google drive (Document sharing platform) where these reports will be stored, and any member can review these reports whenever they need to.

Second Stakeholder Group: Operations Support and Onsite Technicians

This Stakeholder group is consists of two primary teams: Operations Support and Onsite Technicians

Operations support
Technical support analyst
Support center leader

Responsibility: Operations support

The technical support analyst will work closely with the network team and the PM to install the SD-WAN hardware in all the locations. The technical support analyst will also assist the PM in coordinating the tasks and will collect feedback from the associates. The support center leader will be responsible for providing the necessary resources for the support staff and will conduct training on the new technology.

On-site technicians

Justification: on-site technicians

The on-site technical support team will be responsible for providing the necessary resources and tools for the installation of SD-WAN hardware at all the business and office locations. They will provide the necessary support, "on the ground," to the network administrator who will be making the required configuration changes remotely.

The PM can schedule daily installation workshops with this group during the SDWAN design phase to discuss the network topology and SDWAN installation playbook that can be used by the team members daily.

Third Stakeholder Group: Project Leadership and PMO

This Stakeholder group consists of Chief of Operations (COO), Vice President (VP) of IT and PMO, including dedicated PM for this project.

Chief of Operations (COO)

Responsibility: COO

The COO will approve the budget allocated to the project and be responsible for providing any financial resources for the project's completion. The PM and the VP of Infrastructure will update the COO on the project's overall progress (Clarizen, 2017).In this project, the COO will be the main project sponsor, and PM will work with COO in case any changes are necessary in the allocated budget amount.

Vice President (VP) of IT

Responsibility: VP-IT

The VP- IT will work closely with all the technical teams and the PM to allocate the necessary organizational resources for project task completion. He will also approve changes in the network and application architecture, which may be required to complete the project.

Project management office
Project manager
Director - PMO

Responsibility: project management office

The PM will be responsible for the overall progress of the project. He will take care of preparing the project plan, scheduling tasks, and coordinating resources. He will also maintain the project budget and provide regular updates to the project stakeholders. He will also review the overall project portfolio for the organization along with the director of PMO (Project Management Office) to ensure that scheduled tasks do not clash with the major activities of other business areas.

The PM can plan to send below reports to this group using enterprise email.

- Initial Project Charter
- Cost-Benefit Analysis
- Project Plan
- Resource Allocation
- Risk Evaluation
- Product Evaluation reports
- Weekly Project Updates
- Resource utilization
- Business feedback
- Project Closure

The PM should invite all the stakeholders in the initial kick-off meeting of the project to discuss Project scope and his plan for budget and resource allocation. He should gather feedback from all the participants and make final adjustments before he shares the documents with the other groups involved in the project.

Fourth Stakeholder: Associates

Justification: Associates

An associate can be selected from each location to provide feedback on the overall hardware installation service during implementation and on network performance improvement following installation. The associate will also grant any exclusive access or permissions required for installinga new internet circuit or hardware device.

The PM will schedule a meeting with the selected associates to brief them on the project and what all is needed from them to make this project successful. The PM will also share the process of sharing feedback on product performance.

Fifth Stakeholder: SD-WAN technology Partner

Justification: SD-WAN technology partner

The SD-WAN partner will work closely with the network architect during the initial network design. The partner will also provide support to the PM and network administrator in preparing training materials or making decisions on configuration changes.

The PM can plan to send below reports to this group using enterprise email.

- Daily Design reviews and architecture draft (in SDWAN design phase)
- Network Architecture
- Application integration documentation
- Product Performance Matrix
- Project Plan
- Weekly Project Updates
- Project Closure

The PM will involve technical team members from the SDWAN group in the technology workshops with the Network and IT Operations team so that both parties have clear information about their environment. The PM will also schedule product review discussions with the group as and when needed.

VII. Post-Implementation Description

a) Resource Requirement

The project team will share the operations support plan in its handover documentation to the operations team and will request for below resources for post-implementation support.

Onsite Support Team

The onsite support team will be responsible for managing the day-to-day operational tasks related to network changes and monitoring all the alerts. They will be responsible for performing Level1 troubleshooting on all the incidents. This team will escalate the issue to the next level that is either Network or IT operations depending upon the type of alert.

Network Administrator

The Network Operations team will have multiple Network Administrators who will work as a point of escalation for the onsite support team. Few team members from this group can be involved in the initial network design, and they will have in-depth knowledge about the technology and its usage. They will be responsible for coordinating regular software code upgrades. They can engage in SDWAN technical support whenever they need an expert opinion on any support issues, or they need any explanation on how to use new features.

IT Operations

The IT operations will work as another escalation point for the support team to resolve any issues like communication failures with other enterprise applications. This team will be responsible for any new application integration that may come in the future as they have sufficient knowledge of the integration framework. This team can help Onsite Support to setup new performance alerts or add new sites to monitoring tools as and when needed.

b) Maintenance Plan

To maintain and administer the new technology, the project team can plan to share the documents with the IT Network operations and support team.

Short-term maintenance activities:

SDWAN Troubleshooting Guide
SDWAN –New site setup guide

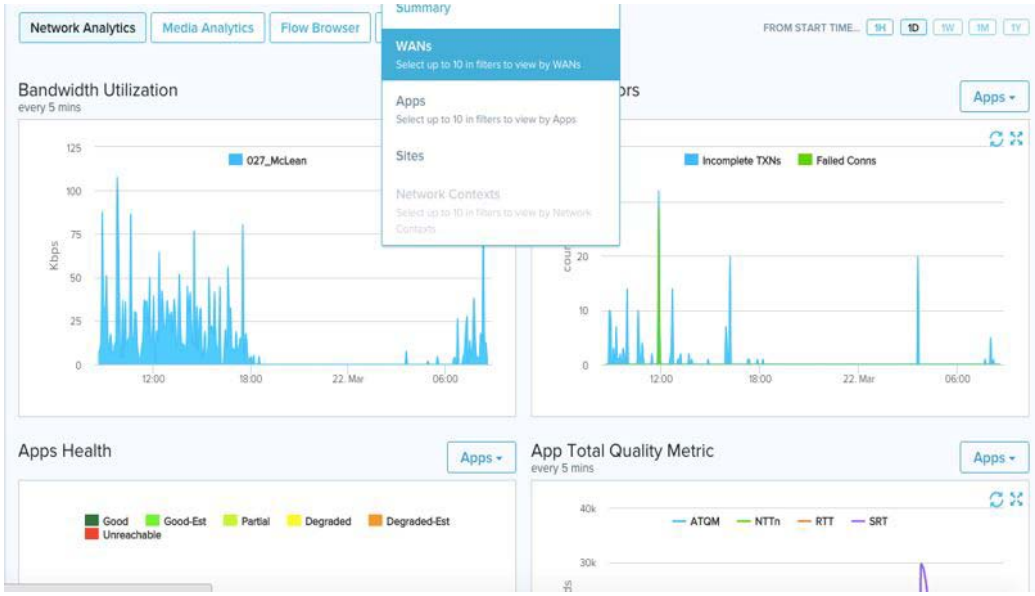
Long-term maintenance activities:

SDWAN Hardware Maintenance Process
SDWAN –New site setup guide
SDWAN software upgrade process

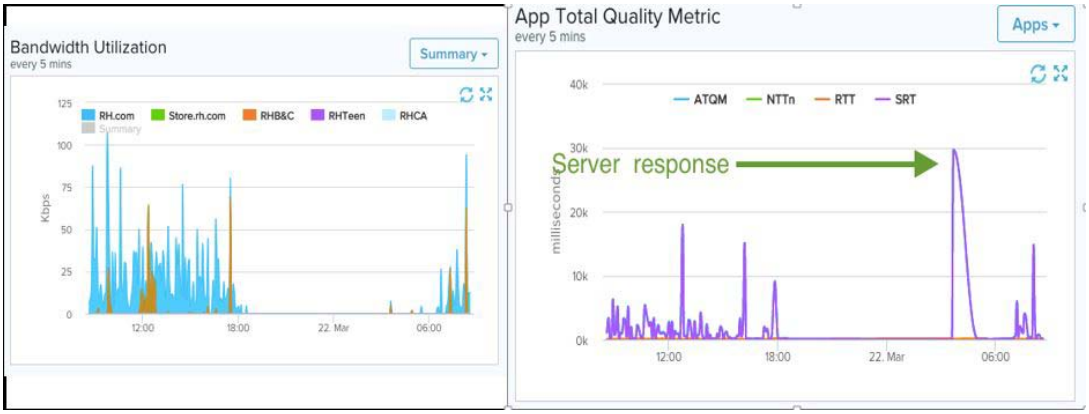
These guides should contain detailed documentation with screenshots on how to maintain the product. A preview of the guide on how to measure the various performance parameters is shown below for reference:

Please login to SDWAN application GUI (Graphic User Interface) using ----- link.

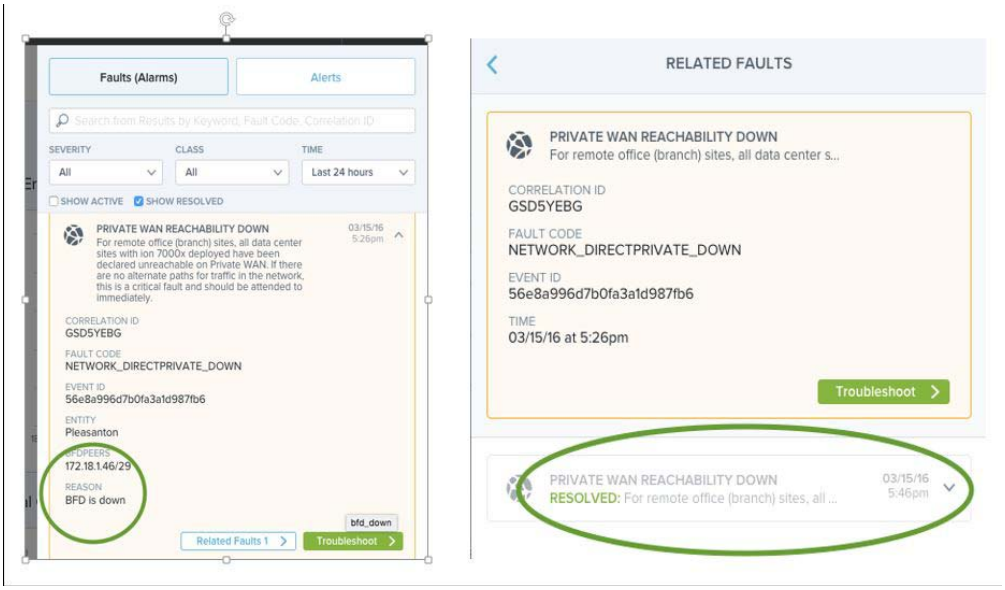
Click on Network Analytics to review bandwidth utilization.



To view the application performance view Application Metric.



To check for the alerts, click on Faults (Alarms); below screenshot shows MPLS (Multiprotocol layer switching) path is not available.



The project team will share a detailed document on how to manage the application upgrade process and how to contact the SDWAN support team, their working hours, and support contract details.

VIII. Post-Implementation Project Summary

a) Deliverables to document the Plan and Process

The Project Team can plan to send below reports/data to all the stakeholders involved to share the success story of the project:

- Locations-Network Performance Report
- Network Incident report
- Sample Pictures that were taken at different locations after successful install
- Associate feedback

Please refer the below sample of a Network performance report of a location that was complaining about the network performance when they were using an older technology.

We have observed that after Circuit upgrade and SDWAN implementation, it has reduced the response time for our organization's website by almost fifty percent. Please refer below screenshot for a location taken from the OOKLA tool that is world-renowned for network performance measurement.

Before Installation: Page Load was taking 7.94 seconds for 90% of the users.

After Installation: Page Load time was reduced to 2.67 seconds for 90% of the users.

b) Criteria and Evaluation Framework

We can evaluate the overall success of the project based on the criteria shown below:

- Improvement in the network performance after completion.
- Ease of implementation of the new technology at the new sites.
- Ease of network administration
- Reduction in network incidents after the final rollout
- Overall operational and process improvements
- The vulnerability reports on the hardware and software.

Please refer below metrics as a reference to measure the proposed and actual outcomes of the project.

Evaluation criterion	Proposed %	Actual %	Business Feedback
Internet bandwidth upgrade	35M	40M	Positive
Network reliability	100%	100%	No Issues
Hardware reliability	100%	100%	No Issues
Ease of installation	40%	30%	No Issues
Ease of access	50%	60%	NA
Network management	50%	70%	NA
Security policies management	60%	80%	NA
Vendor support	50%	40%	NA

IX. Learnings

According to Sabyasachi (n.d.) by collecting and publishing lessons the team learned while completing the previous project, your organization as a whole can benefit. You can help reduce the odds of other groups by making sure they do not repeat the same mistakes and provide insights into how various processes and procedures can be improved overtime. According to Rowe, S. F. & Sikes, S. (2006), most project managers know the importance of capturing lessons learned; it is suitable for the team, organization, existing, and future projects. Lessons learned are the documented information that reflects both the positive and negative experiences of a project. They represent the organization's commitment to project management excellence and the project manager's opportunity to learn from the actual experiences of others I want to mention the below points that I learned from the process of completing this project.

- The more time we spend on initial design and testing, the more we increase the chances of success in completing the project on schedule and achieving our targets.
- We need to involve all the stakeholders from the beginning of the project.
- The PM should inform stakeholders about any changes in the budget, resource allocation, or times lines as soon as possible.
- It is essential to decide on the Project Scope, success criteria, and tools used at the beginning of the project.
- The process of lessons learned should be adapted from the initial implementation stage (not at the end of the project) so that the team can review "What went wrong" and "What needs to be improved." This project manager should use the same forum to discuss "What went right."
- It is better to keep some buffer in terms of resources or timelines in each phase and some cushion in the overall project timelines.

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Performance Evaluation of Software using Formal Methods

By Akinsola, Jide E. T., Kuyoro, Afolashade, O., Adeagbo, Moruf A. & Awoseyi, Ayomikun A.
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Abstract- Formal Methods (FMs) can be used in varied areas of applications and to solve critical and fundamental problems of Performance Evaluation (PE). Modelling and analysis techniques can be used for both system and software performance evaluation. The functional features and performance properties of modern software used for performance evaluation has become so intertwined.

Traditional models and methods for performance evaluation has been studied widely which culminated into the modern models and methods for system and software engineering evaluation such as formal methods. Techniques have transcended from functionality to performance modeling and analysis. Formal models help in identifying faulty reasoning far earlier than in traditional design; and formal specification has proved useful even on already existing software and systems. Formal approach eliminates ambiguity. The basic and final goal of the performance evaluation technique is to come to a conclusion, whether the software and system are working in a good condition or satisfactorily.

Keywords: formal methods, performance evaluation, performance modeling, software performance evaluation, machine learning, markov chains, queuing networks.

GJCST-C Classification: D.2.m

Strictly as per the compliance and regulations of:

Performance Evaluation of Software using Formal Methods

Akinsola, Jide E. T. [α], Kuyoro, Afolashade, O. [σ], Adeagbo, Moruf A. [ρ] & Awoseyi, Ayomikun A. [ω]

Abstract- Formal Methods (FMs) can be used in varied areas of applications and to solve critical and fundamental problems of Performance Evaluation (PE). Modelling and analysis techniques can be used for both system and software performance evaluation. The functional features and performance properties of modern software used for performance evaluation has become so intertwined.

Traditional models and methods for performance evaluation has been studied widely which culminated into the modern models and methods for system and software engineering evaluation such as formal methods. Techniques have transcended from functionality to performance modelling and analysis. Formal models help in identifying faulty reasoning far earlier than in traditional design; and formal specification has proved useful even on already existing software and systems. Formal approach eliminates ambiguity. The basic and final goal of the performance evaluation technique is to come to a conclusion, whether the software and system are working in a good condition or satisfactorily.

Formal methods (FM) or Formal Techniques (FT) for performance evaluation include formalisms for performance modeling (which are Markov chains, queuing networks, stochastic Petri nets, and stochastic process algebras), equivalence checking and model checking, efficient solution techniques, and software performance engineering. Modeling consists of five classes: requirements, activities, connectors, performers, and resources.

The paper focuses on formal methods for performance evaluation using formal modeling with emphasis on Modeled System, Markov Chains, Queuing Networks, Generalized Stochastic Petri Nets, Stochastic Process Algebras, Markovian Behavioral Equivalences and Software Performance Engineering (SPE) in relation tofunctional features and performance properties.

Keywords: formal methods, performance evaluation, performance modeling, software performance evaluation, machine learning, markov chains, queuing networks.

I. Introduction

The term Formal Methods (FM) refers to the use of mathematical modelling, calculation and prediction in the specification, design, analysis and assurance of computer systems and software. The reason it is called formal methods rather than mathematical modelling of software is to highlight the character of the mathematics involved (Rushby, 1995).

According to Wikipedia, the use of formal methods for software and hardware design is motivated by the expectation that, as in other engineering disciplines, performing appropriate mathematical analyses can contribute to the reliability and robustness of a design.

Formal methods (FM) or Formal Techniques (FT) for performance evaluation include formalisms for performance modeling (Markov chains, queuing networks, stochastic Petri nets, and stochastic process algebras), equivalence checking and model checking, efficient solution techniques, and software performance engineering (Bernardo & Hillston, 2007). Collins (1998), opined that formal methods are techniques used to model complex systems as mathematical entities. By building a mathematically rigorous model of a complex system, it is possible to verify the system's properties in a more thorough fashion than empirical testing.

System engineers can inspect the modeled system architecture to determine whether it is acceptable, but few formal methods exist to aid in the performance of this task (Rodano & Giammarcob, 2013). In a safety critical system, ambiguity can be extremely dangerous, and one of the primary benefits of the formal approach is the elimination of ambiguity (Kling, 1994).

Modelling is one of the ways used in presenting performance evaluation. Heuristics can be applied in determining the good characteristics for performance evaluation. Formal methods can be applied to identify the characteristics of a good system architecture using logical notations. Formal method is the fast approach to identify possible problems in any software architectural design (Rodano & Giammarcob, 2013).

Performance evaluation gives a measure of the service delivered by a system (Jean-Yves & Boudec, 2010) and performance is one of the most important non-functional aspects of any (hardware or software) system. Performance evaluation comprises of certain techniques such as direct measurements using test-beds, analytical or simulation modeling which can be applied to existing or envisioned systems like computer systems, communication networks, algorithms and protocols (Jain, 1991). The basic and final goal of the performance evaluation concept is to come to a conclusion, whether the software and system are

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working in a good condition or satisfactorily. This is can be achieved with formal modelling techniques.

Datamining is the discovery of "models" fordata (Leskovec, Rajaraman & Ullman, 2014). According to Anwaar, Junaid, Raihan, Arjuna, Andrej & Jon (2016), datamining normally denotes the automation of pattern discovery and prediction from huge volumes of data using Machine Learning (ML) techniques. Datamining can also be used to denote an Online Analytical Processing (OLAP) or Structured Query Language (SQL) queries that entails retrospectively searching a large data base for a specific query. There has been upsurge in availability of information and device connectivity have brought about increase in application of machine learning (which is a sub-domain Artificial Intelligence (AI) in diverse areas (Akinsola, Awodele, Idowu & Kuyoro, 2020). These areas include applications of Machine Learning (ML) in performance evaluation and verification of software. ML requires application of algorithms for model building using performance metrics. Every performance metric must be considered holistically before choosing an optimal algorithm for predictive analytics (Akinsola, Awodele, Idowu & Kuyoro, 2020).

Formal method axioms can be used in structural evaluation of a software model especially data mining model. The relationships among the various elements of data mining software you be used to evaluate its effectiveness in terms of performance. Formal methods can be used for testing the realization of the entire software against its specification as well as connections between components in order to determine its interoperability.

Characteristics heuristics natural language axioms. The axioms symbolizes syntactic checks that can be used in software performance evaluation. Transformation of axioms into formal language notation is essential in performance evaluation of data mining software. CORE and Innoslate are some of the software engineering tools for software performance evaluation.

The quality of any software for performance evaluation has three sets of factors which are functionality, engineering, and adaptability. They are also referred to as exterior quality, interior quality and future quality respectively. Formal method functionality features are the exterior qualities such as Correctness, Reliability. Usability and Integrity. The engineering features are Efficiency, Testability, Documentation and Structure while the adaptability features are Flexibility, Reusability and Maintainability

II. Literature Review

Axioms are statements that we cannot deny without using them in our denial. Axioms are the foundation of all knowledge. When they are well constructed, the transformation of axioms into formal language notation can be a veritable tool in performance evaluation of data mining software. Formal methods axioms can be used in structural evaluation of a software model especially data mining model.

CORE I is used for analyzing the axioms. Innoslate is a web-based system modeling tool that is based on the Lifecycle Modeling Language (LML)

Model consists of five classes: requirements, activities, connectors, performers, and resources. Resources are data or information that is produced and/or consumed by the system. An activity is an element that transforms inputs into outputs (inputs and outputs are both resources). Performers carry out activities, and physical or logical relationships between performers are known as connectors. Requirements are written specifications for the system (Giammarco, 2012)

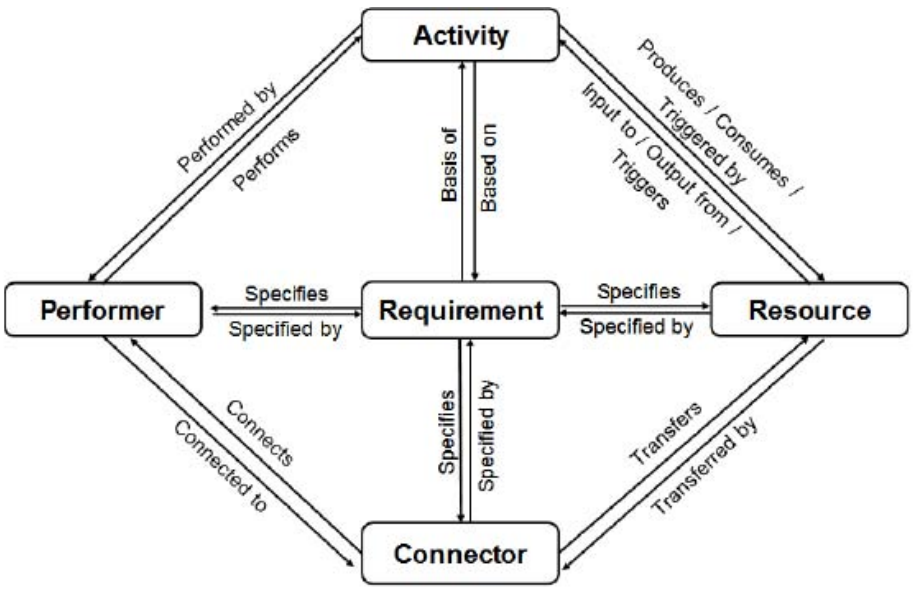

Figure 1: Class / Relationship Diagram of Software Model (Source: Giammarco, 2012)

The axioms for evaluating a modeled software architecture are categorized into five groups: Decomposition, Requirements Traceability, Activity Performance, Input/Output and Connection.

Markov chains have become an accepted technique for modeling a great variety of situations. Formal methods in computer science as a prominent approach to the rigorous design of computer, communication and software systems. Markov chains, the fundamental performance modeling formalism in use since the early 1900s. The success that has accompanied queuing modeling has largely eliminated the need to set up and solve global balance equations numerically. However, as models become more complex, it is becoming increasing evident that there is place for numerical analysis methods in the modelers' toolbox (Stewart, 2007).

Queuing Networks (QNs) have been proved to be a powerful and versatile tool for system performance evaluation and prediction. Queuing networks, a class of stochastic models extensively applied to represent and analyze resource-sharing systems such as communication and computer systems. Product-form queuing networks, allows for defining efficient algorithms to evaluate average performance measures. The main computational algorithms for QNs have been integrated in various software tools for performance modelling and analysis that include user friendly interfaces based on different languages to take into account the particular field of application, e.g., computer networks, computer systems. Basic queuing systems have been defined in queuing theory and applied to analyze congestion systems (Balsamo & Marin, 2007).

Generalized Stochastic Petri Nets (GSPNs), a modeling formalism that can be conveniently used both for the functional verification of complex models of discrete-event dynamic software and systems as well as for their performance and reliability evaluation. The automatic construction of the probabilistic models that underlie the dynamic behaviors of these nets rely on a set of results that derive from the theory of untimed Petri Nets. Petri nets are a powerful tool for the description and the analysis of systems that exhibit concurrency, synchronization and conflicts. There is general consensus that the only means of successfully dealing with large models is to keep them simple by using a "divide and conquer" approach in which the solution of the entire model is constructed on the basis of the solutions of its individual components (Balbo, 2007).

Process algebras emerged as a modelling technique for the functional analysis of concurrent systems approximately twenty years ago. Over the last 17 years there have been several attempts to take advantage of the attractive features of this modelling paradigm within the field of performance evaluation. Stochastic Process Algebras (SPA) were first proposed as a tool. Stochastic process algebras and their use in performance modeling, with a focus on the PEPA formalism is highly efficient for evaluation. The compositional modeling capabilities of the formalism and the tools available to support Markov-chain based analysis are good for formal models building (Clark, Gilmore, Hillston, & Tribastone, 2007).

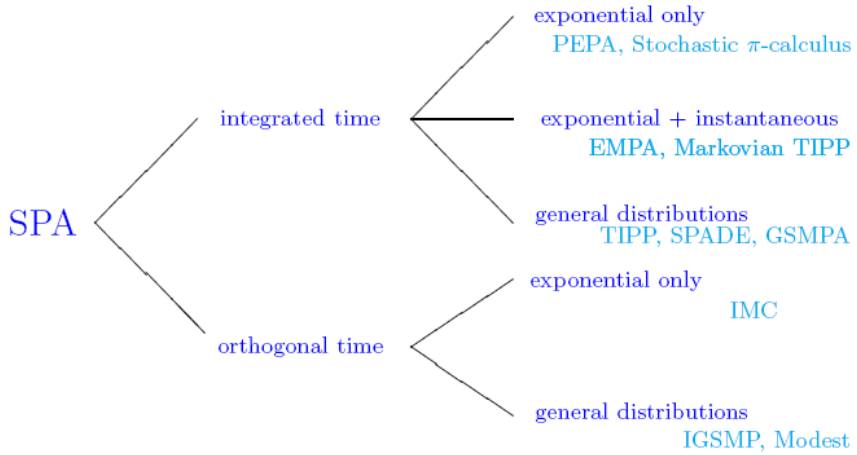

Figure 2: Classification of the stochastic process algebras (Source: Clarke et al., 2007)

The formality of the process algebra approach allows assigning of a precise meaning to every language expression. This implies that once we have a language description of a given system its behavior can be deduced automatically (Clarke et al., 2007)

Performance-oriented notations provide the designer with the capability of building performance aware system models, which can be used in the early development stages to predict the satisfy ability of certain performance requirements as well as to choose

among alternative designs on the basis of their expected Quality of Service (QoS) guarantees. Markovian behavioral equivalences with respect to a number of criteria such as their discriminating power, the exactness of the Markov-chain-level aggregations they induce, the achievement of the congruence property, the existence of sound and complete axiomatizations, the existence of logical characterizations, and the existence of efficient verification algorithms can provide satisfactory analysis with respect to certain criteria such as exact aggregation, congruence property , sound and complete axiomatization, logical characteristics and verification complexity (Bernardo, 2007).

Probability is an important component in the design and analysis of software and hardware systems. In distributed algorithms electronic coin tossing is used as a symmetry breaker and as a means to derive efficient algorithms, Model checking for both discrete-time and continuous-time Markov chains, which deals with algorithms for verifying them against specifications written in probabilistic extensions of temporal logic, including quantitative properties with rewards supports probabilistic modeling such as Probabilistic Symbolic Model (PRISM) checker (Kwiatkowska, Norman & Parker, 2007).

Software performance engineering (SPE) is a systematic, quantitative approach to constructing software systems that meet performance requirements. SPE provides an engineering approach to performance, avoiding the extremes of performance-driven development and "fix-it-later." SPE uses model predictions to evaluate trade-offs in software functions, hardware size, quality of results, and resource requirements. Two SPE models provide the quantitative data for SPE: the software execution model and the system execution model. The software execution model represents key facets of software execution behavior. The model solution quantifies the computer resource requirements for each performance scenario. The system execution model represents computer system resources with a network of queues and servers. The model combines the performance scenarios and quantifies overall resource utilization and consequent response times of each scenario (Smith, 2007).

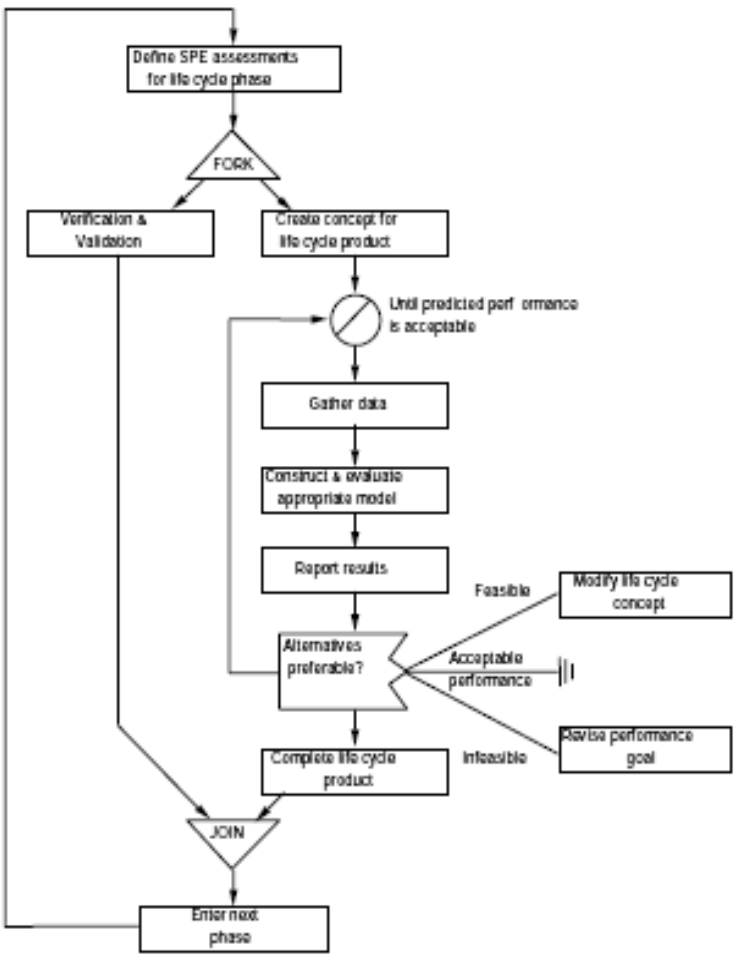

Figure 3: Software Performance Engineering Process (Source: Smith, 2007)

III. Merits and Demerits of Formal Methods for Performance Evaluation

a) Merits

It is effectual to write a specification formally rather than writing an informal specification and then translating it. To detect inconsistency and incompleteness, it is efficient to analyze the formal specification as early as possible (Mona, Amit & Meenu, 2010). Given below are some of the merits of formal methods in software performance evaluation:

i. *Measure of correctness:* The use of formal methods provides a measure of the correctness of a system, as opposed to the current process quality measures.
ii. *Early defect detection:* Formal Methods can be applied to the earliest design artifacts, thereby leading to earlier detection and elimination of design defects.
iii. *Guarantees of correctness:* Formal analysis tools such as model checkers consider all possible execution paths through the system. If there is any possibility of a fault/error, a model checker will find it. In a multithreaded system where concurrency is an issue, formal analysis can explore all possible interleaving and event orderings. This level of coverage is impossible to achieve through testing.
iv. *Error Prone:* Formal description forces the writer to ask all sorts of questions that would otherwise be postponed until coding. This helps to reduce the errors.

b) Demerits

Formal methods are generally viewed with suspicion by the professional engineering community (Bowen, 93). Given below are some of the demerits of formal methods in software performance evaluation:

i. *Expansive*

Formal Methods are expense. This is because of the rigor involved, formal methods are always going to be more expensive than traditional approaches to engineering. Also, the tool development cost is high.

ii. *Limits of Computational Models*

While not a universal problem, most formal methods introduce some form of computational model, usually hamstringing the operations allowed in order to make the notation elegant and the system provable. Unfortunately, these design limitations are usually considered intolerable from a developer's perspective.

iii. *Usability*

Traditionally, formal methods have been judged on the richness of their descriptive model. That is, 'good' formal methods have described a wide variety of systems, and 'bad' formal methods have been limited in their descriptive capacities.

iv. *Adaptability*

SPE activities are not easy to adapt and economical for future environments. So it needs to evolve in order to make SPE adaptable.

IV. Conclusion

Formal Methods (FM) is a very active research area with a wide variety of methods and mathematical models. There is not available any one method that fulfills all the related needs of building a formal specification. Just like the No Free Lunch theorem is highly essential in the field of machine learning because good number of correctly classified instances in predicting valid disease outcomes using supervised machine learning techniques is not just a function of accuracy (Akinsola, Adeagbo, Awoseyi, Ayomikun, 2019).Performance evaluation of software using formal methods can be carried out using hybridization of machine learning and Multi Criteria Decision Making (MCDM) techniques. MCDM methods can be used to find the optimal classification and regression models in relation to supervised machine learning algorithms (Akinsola, Kuyoro, Awodele & Kasali, 2019).

Researchers and practitioners are continuously working in this area and there by gaining the benefits of using formal methods. Furthermore, formal methods are only part of the solution to the problem related to requirement analysis and success depends crucially on integrating them into a larger process. Formal method axioms are being used in structural evaluation of a software model especially data mining model. Survey of Markovian Behavioral Equivalences supports a merely qualitative analysis, in the sense that it only allows one to establish whether two models pass an arbitrary test in the same way.

Generalized Stochastic Petri nets (GSPNs) can be conveniently used for the analysis of complex models of Discrete Event Dynamic Systems (DEDS) and for their performance and reliability evaluation. Classical Process algebra (CPA) can be used to develop models which may be used to calculate performance measures as well as deduce functional properties of the system.

Markovian Bisimilarity ~MB, Markovian Testing equivalence ~MT, and Markovian Trace equivalence ~MTr with respect to a number of criteria such as exact aggregation, congruence property , sound and complete axiomatization, logical characteristics and verification complexity can be used to model by taking advantage of symmetries within the model. Stochastic model checking can be used to cover both the theory and practical aspects for two important types of probabilistic models such as discrete- and continuous-time Markov chains.

Software Performance Engineering (SPE) should become better integrated into capacity planning. There has been a tremendous amount of research in the

SPE field since it was first proposed as a discipline in 1981. The emphasis will change from finding and correcting design flaws to verification and validation that the system performs as expected. The verification and validation can be implemented using predictive analytics with proper application of the best fit machine learning algorithms. Supervised predictive machine learning, ML algorithms require precise accuracy and minimum errors in addition to putting several factors into consideration (Osisanwo, Akinsola, Awodele, Hinmikaiye, Olakanmi & Akinjobi, 2017)

Software Application Gap Analysis

Software assessment must be determined in a manner whether business requirements are being met, if not, what steps should be taken to ensure they are met successfully. The following must be considered for critical performance evaluation.

1. The natural language axioms deals with first-order predicate logic notation, therefore, it cannot be used for implementing more complex software performance evaluation.
2. The axioms are too generic and might not be robust enough to cope with evaluating certain software classes effectively. Therefore, domain specific axioms should be developed
3. The verification and validation components of the software performance evaluation process should include more analyzer to make it efficient and highly scalable with focus on machine learning.
4. In Markovian Behavioral Equivalences none of the proposals seems to induce an exact aggregation at the Continuous-Time Markov Chains (CTMC) level
5. Markov chains focuses on numerical analysis of modelling but cannot handle novel approaches concerning the special structures in performance evaluation, thus cannot handle complex models.
6. There is need for the development of the solid theoretical framework of model construction and analysis for Generalized Stochastic Petri nets (GSPNs).
7. Determination of the execution probability and the average duration of the computations in the presence of passive transitions is highly is a challenge. Also, the set of logical operators necessary to characterize Markovian behavioral equivalences decreases as the discriminating power of the equivalences decreases.
8. PRISM model checker for stochastic model checking may prove too simplistic for some modelling applications.
9. There is need to extend the quantitative methods to model emerging hardware-software developments, to extend hardware-software measurement technology to support SPE, and to develop interdisciplinary techniques to address the more general definition of performance.

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Intelligence without Data

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Abstract- This article explores intelligence without data. More specifically, it reveals what the study of big data ignores in the trinity age of big data, analytics, and intelligence, and looks at DIKEW intelligence through presenting an integrated framework of intelligence. It then examines intelligence without data and wisdom algebra. It demonstrates that intelligence without data consists of information intelligence without data, knowledge intelligence without data, experience without data, intelligence without data, and wisdom intelligence without data, based on the hierarchy of wisdom. It argues that big data must incorporate intelligence without data to serve the world. At the same time, intelligence without data could enhance human intelligence, cognitive intelligence, machine intelligence, and business intelligence.

Keywords: *DIKEW intelligence, data, information, big data, knowledge, artificial intelligence, wisdom.*

GJCST-C Classification: *I.2.m*

Strictly as per the compliance and regulations of:

Intelligence without Data

Zhaohao Sun[α] & Yanxia Huo[σ]

Abstract- **This article explores intelligence without data. More specifically, it reveals what the study of big data ignores in the trinity age of big data, analytics, and intelligence, and looks at DIKEW intelligence through presenting an integrated framework of intelligence. It then examines intelligence without data and wisdom algebra. It demonstrates that intelligence without data consists of information intelligence without data, knowledge intelligence without data, experience without data, intelligence without data, and wisdom intelligence without data, based on the hierarchy of wisdom. It argues that big data must incorporate intelligence without data to serve the world. At the same time, intelligence without data could enhance human intelligence, cognitive intelligence, machine intelligence, and business intelligence.**

Keywords: DIKEW intelligence, data, information, big data, knowledge, artificial intelligence, wisdom.

I. Introduction

Intelligence without data reflects a social reality because most people live in the environment of intelligence without data, although they are living in the age of big data (Sun & Wang, 2017). Big data are generated from various instruments, billions of calls, texts, tweets, phones, payment systems, cameras, sensors, Internet transactions, emails, videos, clickstreams, social networking services, and other sources (Henke & Bughin, 2016). Big data has become one of the most important research frontiers for innovation, research, and development (Chen & Zhang, 2014) (Sun & Huo, 2019). Big data and its emerging technologies including big data analytics and Hadoop (Coronel, Morris, & Rob, 2015) have been not only making dramatic changes in the way the business, e-commerce and cloud services operate but also making traditional data analytics and business analytics bring new opportunities for academia, industry, and government (Sun, Sun, & Strang, 2016) (Howson, Richardson, Sallam, & Kronz, 2019).

The nomenclature "intelligence" means intelligence in artificial intelligence (AI), machine intelligence, cognitive intelligence, and human intelligence (Sun & Wang, 2017) (Wang, 2015). This building block has a history of at least three scores ever since 1956 (Russell & Norvig, 2010) (Sun & Wang, 2017). Big data intelligence (BDI) is a kind of intelligence driven by big data (Sun, Sun, & Strang, 2016) (Sun, Strang, & Li, 2018). However, either AI or machine intelligence or BDI has technically ignored significant and fundamental questions on intelligence, that is,

1. What is intelligence without data?
2. How can classify intelligence without data?
3. What is the impact of intelligence without data on AI?

These questions are significant because people can live without data sometimes; people have intelligence without data sometimes. On the other hand, these questions are fundamental for AI and machine learning because if we can understand the above issues better, then people need not explore deep learning using a waste set of big data and oversupplied funds. People can enjoy the environment without data sometimes.

This article addresses intelligence without data, different from the linear traditional thinking of big data, and intelligence (Sun & Wang, 2017). More specifically, it reveals what the research of big data ignores in the trinity age of big data, analytics, and intelligence. It looks at DIKEW intelligence through presenting an integrated framework of intelligence. The research demonstrates that intelligence without data consists of information intelligence without data, knowledge intelligence without data, experience intelligence without data, and wisdom intelligence without data. It argues that big data can incorporate intelligence without data to serve the world; at the same time, intelligence without data can enhance human intelligence and machine intelligence as well as business intelligence.

The remainder of this article is organized as follows: Section 2 looks at DIKEW intelligence by presenting an integrated framework of intelligence. Section 3 explores intelligence without Data. Section 4 examines wisdom algebra. Section 5 provides a unified perspective on intelligence without data and illustrates intelligence without data using a few examples. Section 6 and 7 discuss implications and end this article with some concluding remarks and future work.

II. DIKEW Intelligence: An Integrated Framework of Intelligence

In the big data world, it seems that all digital things online are data, but much of it is not really "data" outside the big data world (Williams, 2016, p. 34). Information, knowledge, experience, and wisdom are

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more popular than data in computer science, business and management, and many other fields. This section will overview them and explore DIKEW intelligence using an integrated framework.

a) DIKEW Hierarchy

Data, information, knowledge, experience, and wisdom (DIKEW) form a hierarchical structure with a pyramid as a basis of intelligence (e.g., human intelligence, cognitive intelligence, AI, and machine intelligence) (Sun & Finnie, 2004; 2010) (Sun & Finnie, 2005) (Rowley, 2007) (Wang, 2015) (Liew, 2013), as shown in Figure 1. DIKEW is an extended form with the reverse pyramid of DIKW (Rowley, 2007; Wang, 2015) (Sun & Finnie, 2003) (Liew, 2013). Data are raw, unorganized and unprocessed materials such as facts, numbers, signals, assertions, perceptions or observations that represent the properties of objects and events (Rowley, 2007) (Wang, 2015). Data usually are devoid of meaning, context, content, and value (Sabherwal & Becerra-Fernandez, 2011).

Information is processed data, a set of data, with the usefulness, content, relevance, purpose, and value (Ackoff, 1992; Sabherwal & Becerra-Fernandez, 2011). For example, the manipulation of raw data for a company, as a data processing, is to obtain more meaningful information on the trend for daily sales (Sabherwal & Becerra-Fernandez, 2011).

Knowledge is processed, organized, or structured information with the insight of experts (Laudon & Laudon, 2016) (Liew, 2013). Knowledge is a central concept in intelligent systems and cognitive systems (Wang, 2015) (Sun & Finnie, 2004; 2010). In computer science and information science, knowledge is usually defined as the beliefs, objects, concepts, and relationships that are assumed to exist in some areas of interest (Sabherwal & Becerra-Fernandez, 2011), for example, knowledge discovery from a large database (Sun & Finnie, 2005).

Experience can be taken as previous knowledge and skill one obtained in the past or through social practice for some time (Sun & Finnie, 2005) (Oxford, 2008). In computer science, business and management, experience-based reasoning and experience management are important for understanding human reasoning and knowledge management (Sun & Finnie, 2005) (Sun & Finnie, 2004; 2010). Case-based reasoning is a kind of experience-based reasoning (Finnie & Sun, 2003).

Wisdom is defined as "the ability to make sensible decisions and give good advice because of experience and knowledge that you have" (Oxford, 2008) (Liew, 2013). Wisdom can be defined as the ability to increase effectiveness through processing experience, knowledge, information, and data, all together (Ackoff, 1992). Wisdom adds value through appropriate judgments and creative ideas (Rowley, 2007). For example, the key idea in Page Rank of Google is a wisdom. The business model of Uber is also a business wisdom. Wisdom usually consists of revolutionary ideas that can bring big decisions and value for an organization. A question for wisdom is as follows. Why has only Peter pointed out such a wisdom in our big organization? Therefore, wisdom is closest to innovation, creativity, and ingenuity, comparing with experience, knowledge, information, and data, although the latter can be used for producing wisdom.

We have the following relationships among data, information, knowledge, experience, and wisdom based on the above discussion (Sun & Xiao, 1994) (Johnsonbaugh, 2013).

$$\text{Data} \sqsubset \text{information} \sqsubset \text{knowledge} \sqsubset \text{experience} \sqsubset \text{widom} \quad (1)$$

These relationships can be illustrated in Figure 1, which can be also considered as the DIKEW pyramid.

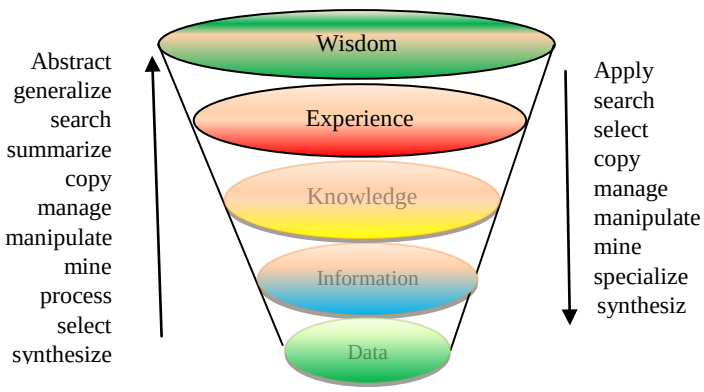

Fig. 1: Interrelations among data, information, knowledge, experience and wisdom

In the DIKEW pyramid, information is defined in terms of data (Rowley, 2007), knowledge in terms of information and data (Sabherwal & Becerra-Fernandez, 2011), experience in terms of knowledge, information, and data (Sun & Finnie, 2004; 2010), and wisdom in terms of experience, knowledge, information, and data.

DIKEW can be considered as a dimension as enabling components or techniques to develop intelligence.

There are two transformations in this DIKEW hierarchy, as illustrated in Figure 1. The first is the data-to-information-to-knowledge-to-experience-wisdom transformation, it can be called bottom-up transformation. This transformation reflects operations such as abstract (Wang, 2015), generalize, mine, process, manipulate, select, copy, summarize, and search, to name a few, from data up to wisdom via information, knowledge and experience. For example, data mining is a data-to-information-to-knowledge technique that transforms data and information to knowledge (Kantardzic, 2011), because the knowledge discovery from a database is the key task of data mining (Sun, Sun, & Strang, 2018). Search, select, and copy are fundamental transformation from data up to wisdom in the age of big data and the age of the Internet.

The second is the wisdom-to-experience-to-knowledge-to-information-to-data transformation; it can be called top-down transformation. This transformation usually includes operations such as specify, process, manipulate, select, apply, and search, to name a few. For example, how to use Uber to book a car for traveling from the city mall to the university is a kind of application. One then needs to search and select the nearest Uber car to realize "service provision just as booked" using a smartphone.

Each of above-mentioned transformation corresponds to a series of ICT techniques, algorithms, and methods. For example, the management of data includes database definition language (DDL) and structured query language (SQL) in database management systems (Coronel, Morris, & Rob, 2015). Search and selection have been realized through search engines like Google and Baidu in the big data age. It is a life-long time study for one to properly search and select right data or information or knowledge or experience or wisdom.

It should be noted that establishing correspondences between these two bidirectional transformations (in Figure 1) and the ICT techniques, algorithms, and methods are the tasks of DIKEW computing. DIKEW computing consists of data computing, information computing, knowledge computing, experience computing, and wisdom computing, where computing is about computing science, technology, engineering, management, and systems (ACM/IEEE/AIS, 2019). For example, data computing includes data science, technology, engineering, management and systems, and so on. Therefore, DIKEW computing covers almost all the activities of current ICT with applications.

We searched Amazon.com, and have not found a book whether on "wisdom science" or on "engineering of wisdom" or "wisdom engineering," but there is one book on "management of wisdom" or "wisdom management," that is, Optimal Knowledge Management: Wisdom Management Systems Concepts and Applications (Thierauf & Hoctor, 2006). However, this book focuses on "the essentials of knowledge management, business intelligence, and smart business systems" rather than wisdom management. This research demonstrates that wisdom computing in general, wisdom science, wisdom management, wisdom engineering in specific have not yet drawn much intention in academia and industries. However, some have tried to do so (McDonald, 2017). This paper does not go into each of them because of the limitation of space and beyond the scope of this research. Instead, we look into DIKEW intelligence.

b) Basic Intelligence

Intelligence is the ability of "learning, thinking, and understanding" (Oxford, 2008). These three abilities are the core of basic human intelligence. Machine learning including deep learning aims to automate ability of human learning through "improving the performance on future tasks after making observations about the world" (Russell & Norvig, 2010, p. 693). However, only learning, thinking, and understanding are not enough in modern society, because a human is also a social animal, connecting (or connect) should be another component of human intelligence. Advanced communication technologies and tools such as mail, telephone, fax, email, and information sharing on the Web aim to develop the skill of connecting (communication) as a form of intelligence. For example, the current advanced ICT technology and system (Laudon & Laudon, 2016) have brought about social networking services such as Facebook, LinkedIn, and WeChat. All these have developed the skill of connecting as a part of intelligence (e.g., human intelligence).

Therefore, the dimension of intelligence (e.g., human intelligence) consists of learning, thinking, understanding, and connecting.

c) DIKEW intelligence: An Integrated Framework of Intelligence

The above discussion leads to present an integrated framework for intelligence, as illustrated in Table 1, which can also be called DIKEW intelligence.

In Table 1, from left to right (Dimension 1), the first row presents basic intelligence: learning, thinking, understanding, and connecting. From top to bottom (Dimension 2), the first column represents enabling components: wisdom, experience, knowledge, information, and data.

Table 1: An integrated framework for intelligence

Enabling Components	Basic Intelligence				DIKEW intelligence
	Learning	Thinking	Understanding	Connecting	
wisdom	Wisdom based learning	Wisdom based thinking	Wisdom based understanding	Wisdom based connecting	Wisdom intelligence
experience	Experience based learning	Experience based thinking	Experience based understanding	Experience based connecting	Experience intelligence
knowledge	Knowledge based learning	Knowledge based thinking	Knowledge based understanding	Knowledge based connecting	Knowledge intelligence
information	information based learning	information based thinking	information based understanding	information based connecting	Information intelligence
data	data based learning	data based thinking	data based understanding	data based connecting	Data intelligence

In the data row, we have data-based learning, thinking, understanding, and connecting. All these are a main part of data-based intelligence, for short, data intelligence (Chrimes, Kuo, Moa, & Hu, 2017). Data Intelligence has played a significant role in the age of big data analytics (Sun, Strang, & Li, 2018).

In the information row, we have information-based learning, thinking, understanding, and connecting. All these are the main part of information-based intelligence, for short, information intelligence (Hauch, Miller, & Cardwell, 2005). Information intelligence also includes the process of transforming data into information (Guang, Nie, & Li, 2009), because any transformation mentioned above is a kind of intelligent activity.

In the knowledge row, we have knowledge-based learning, thinking, understanding, and connecting. All these are the main part of knowledge-based intelligence, for short, knowledge intelligence (Guang, Nie, & Li, 2009). Knowledge intelligence also includes the process of transforming data into information and transforming data and information into knowledge.

In the experience row, we have experience-based learning, thinking, understanding, and connecting. All these are the main part of experience-based intelligence, for short, experience intelligence (Blake-Plock, 2017). Experience intelligence also includes the process of transforming data, information, knowledge into experience.

In the wisdom row, we have wisdom-based learning, thinking, understanding, and connecting. All these are the main part of wisdom-based intelligence, for short, wisdom intelligence (Ma, 2020). Wisdom intelligence also includes the process of transforming data, information, knowledge, experience into wisdom.

Therefore, DIKEW intelligence consists of data intelligence, information intelligence, knowledge intelligence, experience intelligence, and wisdom intelligence, as listed in the rightest column of Table 1. Combing this result and Figure 1, we have the following inclusion relationship for DIKEW intelligence:

$$\text{data intelligence} \subset \text{information intelligence} \subset \text{knowledge intelligence} \subset \text{experience intelligence} \subset \text{wisdom intelligence} \quad (2)$$

Machine learning can be considered as a part of data intelligence or big data intelligence (Sun & Huo, 2019). We seldom consider machine learning to be a part of information intelligence, knowledge intelligence, experience intelligence, and wisdom intelligence. In this regard, DIKEW intelligence could be ranked from lowest to highest. Wisdom intelligence is the highest intelligence, whereas data intelligence is the lowest intelligence. Therefore, machine learning is still a part of the lowest intelligence. AI has not realized the highest intelligence like wisdom intelligence to some extent. The above analysis provides an answer to why wisdom intelligence has not drawn significant attention in computer science, data science, and artificial intelligence (Ma, 2020).

III. Intelligence Without Data

As mentioned above, data is the raw material for computer (computing machinery) processing. The processed data is information. Knowledge is the

processed information with the help of experts (Laudon & Laudon, 2016). Experience is processed knowledge from social practice. Wisdom can be defined as the collective and individual experience of applying knowledge, information, and data to solve problems (Laudon & Laudon, 2016, p. 462). Wisdom is the integrated form of processed data, information, knowledge, and experience (Sun & Finnie, 2004; 2010). Therefore, transformation from data up to wisdom is a process of applying ICT to each of them. The corresponding ICT technologies consist of data processing and management, information processing and management, knowledge processing and management, experience processing and management, wisdom processing and management to obtain DIKEW intelligence.

In the age of trinity, big data, analytics and AI (Minelli, Chambers, & Dhiraj, 2013) (Sun & Wang, 2017) (Sun Z., 2019), most people including researchers and developers have flattened the hierarchical structure from data via information, knowledge, and experience up to wisdom to data level, so that wisdom, experience, knowledge, and information have been used as data without any doubt (see Fig. 1). In other words, wisdom as data, experience as data, knowledge as data, and information as data become popular. Similarly, in the age of knowledge, most people would consider wisdom, experience, information, and data as knowledge. Therefore, there lacks some rigor in the usage of wisdom, experience, knowledge, information, and data in the academic community.

From Figure 1, we can infer, based on set theory (Sun & Xiao, 1994) (Sun & Wang, 2017), that.

$$\text{Information} = (\text{Information - data}) \cup \text{data},$$
$$\text{Knowledge} = (\text{Knowledge - data}) \cup \text{data},$$
$$\text{Experience} = (\text{experience - data}) \cup \text{data},$$
$$\text{Wisdom} = (\text{wisdom - data}) \cup \text{data}.$$

Remark: These four formulas will also be verified in the next section.

In other words,

- Information is the union of a set of information without data and a set of data,
- Knowledge is the union of a set of knowledge without data and a set of data,
- Experience is the union of a set of experience without data and a set of data,
- Wisdom is the union of a set of wisdom without data and a set of data.

Integrating these discussions with what we mentioned in the previous section on DIKEW, the following is valid.

- Information intelligence is the union of a set of information intelligence without data and a set of data intelligence.
- Knowledge intelligence is the union of a set of knowledge intelligence without data and a set of data intelligence.
- Experience intelligence is the union of a set of experience intelligence without data and a set of data intelligence.
- Wisdom intelligence is the union of a set of wisdom intelligence without data and a set of data intelligence.

Therefore, intelligence without data consists of information intelligence without data, knowledge intelligence without data, experience intelligence without data, and wisdom intelligence without data.

IV. Wisdom Algebra

This section looks at wisdom algebra. Different from the wisdom hierarchy (Rowley, 2007) and experience hierarchy (Sun & Finnie, 2004; 2010), this discussion can be considered as a deep investigation into the DIKEW hierarchy.

Definition 1: Let O be a set of operations, S is a non-empty set, then $< S, O >$ is an algebra (Sun & Xiao, 1994). Algebra is a kind of algebraic system, which can be considered as a mathematical abstraction of systems such as software systems, communication systems, and operational systems.

Definition 2: Let U be a universe of all wisdom, experience, knowledge, information, and data. O is a set of operations. Then $< U, O >$ is a wisdom algebra.

Now we elaborate O as a set of operations, each operation is an abstraction of computer processing in general and an ICT technique, an algorithm, and a method in specific. At a relatively lower level, an operation is an abstraction of a "click", or abstraction of a command related to a program. Based on the above discussion, an algorithm discussed in AI, computer science, data science, and information technology, is an operation sequence (Russell & Norvig, 2010) (Kantardzic, 2011).

At a higher level, computer processing includes data processing and management, information processing and management, knowledge processing and management, experience processing and management, and wisdom processing and management.

More generally, if $D \subset U$ is the set of all data, $O_d \sqsubset O$ is the set of operations, then $< D, O_d >$ is data algebra, a mathematical abstraction of data processing and management system. For example, when O_d includes select, project, and join, then $< D, O_d >$ can be considered as a database algebra, an abstraction of database management systems (Coronel, Morris, & Rob, 2015).

If $I \subset U$ is the set of all data and information, $O_i \sqsubset O$ is the set of operations for processing and

managing information, then $< I, O_i >$ is an information algebra, a mathematical abstraction of information processing and management systems. When O_i includes operations for information management and information systems, then $< I, O_i >$can be considered as an abstraction of information management systems (Laudon & Laudon, 2016). For example, when O_i includes collect, analyze, and visualize, then $< I, O_i >$ can be considered as an information algebra, an abstraction of information systems (Laudon & Laudon, 2016, p. 397).

If $K \subset U$ is the set of all data, information, and knowledge, $O_k \sqsubset O$ is the set of operations for processing and managing knowledge, then $< K, O_k >$ is a knowledge algebra, a mathematical abstraction of a knowledge processing and management system. When O_k includes operations for knowledge reasoning and knowledge management, then $< K, O_k >$ can be considered as an abstraction of knowledge management systems (Laudon & Laudon, 2016).

If $E \subset U$ is the set of all data, information, knowledge,and experience, $O_e \sqsubset O$ is the set of operations for processing and managing experience, knowledge, and data, then $< E, O_e >$is an experience algebra, a mathematical abstraction of an experience-based system (Sun & Finnie, 2005). Case–based reasoning (CBR) is a kind of experience-based reasoning. CBR has five operations, that is, case retrieval, reuse, revision, retention, and repartition (Finnie & Sun, 2003), then $< E, O_e >$ can be considered as a case-based algebra, an abstraction of case-based systems (Sun & Finnie, 2005).

If $W \subset U$ is the set of all data, information, knowledge, experience, and wisdom, $O_w \sqsubset O$ is the set of operations for processing and managing wisdom, experience, knowledge, information, and data, then $< W, O_w >$ is a wisdom algebra, a mathematical abstraction of wisdom processing and management systems.

Generally, for any wisdom w, there exist some data d and operators $o_d \in O_d, o_i \in O_i, o_k \in O_k, o_e \in O_e$ such that

$$w = o_e(o_k(o_i(o_d(d))))$$

In other words, data can generate wisdom through computer processing or transformation of data into information, knowledge, and experience.
When $o_d = i_d$, $o_i = i_i$, $o_k = i_k$, $o_e = i_e$, $o_w = i_w$ are identity operators, then

$$w = i_w(i_e(i_k(i_i(i_d(d)))))$$

And $w = i_w(w)$. That is, through identity transformation, data has been transformed into information, information into knowledge, knowledge into experience, experience into wisdom, and wisdom can be transformed into wisdom through identity transformation, so do experience, knowledge, and information. This conforms to the work of (Rowley, 2007) in that information is defined in terms of data, etc. It also demonstrates the soundness of the DIKEM hierarchy in Figure 1. This also demonstrates that data is a part of the set of all the information, which proves that the statement of "information is a subset of data" (Sabherwal & Becerra-Fernandez, 2011) is not valid. The concise representation of all the information is as follows.

Information = data + processed data.

i_d , i_i , i_k , i_e , and i_w are allidentity operators, each of them is a mathematical representation (or abstraction) of ICT functions such as photocopy, copy, scan, print, and fax. Just as print, copy, and scan for ICT systems, identity operations are crucial for wisdom algebra because they keep the integrity of data, information, knowledge, experience, and wisdom.

More generally, based on the discussion of Section 2.1, we briefly have that

$$O_d(Data) = Information,$$
$$O_i(Information) = Knowledge,$$
$$O_k(Knowledge) = Experience,$$
$$O_e(Experience) = Wisdom.$$

Therefore, we have

$$(O_d - i_d)(Data) = Information\ without\ data,$$
$$(O_i - i_i)(Information) = Knowledge\ without\ data,$$
$$(O_k - i_k)(Knowledge) = Experience\ without\ data,$$
$$(O_e - i_e)(Experience) = Wisdom\ without\ data.$$

Remark: data, information, knowledge and experience in the parentheses should be replaced by *D*, *I*, *K*, *E* respectively in order to keep mathematical integrity. The above representations can appeal to more readers.

V. Intelligence Without Data: A Unified Perspective

This section will illustrate intelligence without data using examples from a unified perspective, based on the above-proposed wisdom algebra.

a) Information intelligence without data

We use Q-A-R (Question-Answer-Remark) (Sun & Finnie, 2005) to differentiate information from knowledge as follows.

Q1: What are you learning in your school?
A1: I am learning knowledge.
R1: Few say that "I am learning information".

Now we differentiate information from data as follows.

Q2: Do you know data about PA5510898?
A2: I believe that this is an Australia passport number.
R2: Few say that "Do you know information about PA5510898". The answer A2 has been based on the knowledge or experience of the person. Maybe s/he has a friend with an Australian passport.

The answer A2 is correct, after computer processing, one finds that Dr. Peter Davison (an artificial name) is the holder of the Australian passport with the No. PA5510898. Peter is a millionaire in real estate and lives in Melbourne. The information is processed based on the data PA5510898 using a computer software. Therefore, such information-driven intelligence is information intelligence without data.

Remark: the above discussion implies that data is any data, information, knowledge, experience that as an input for computer processing.

b) Knowledge intelligence without data

Algebra is a system without data (Sun & Xiao, 1994). Mathematical logic is a logical system without data (Russell & Norvig, 2010).Graph theory is a system without data. We use Q-A-R (Question-Answer-Remark) to differentiate knowledge from data (Sun & Finnie, 2005).

Q3: What do you study at the university?
A3: I study the knowledge on logic, algebra and graph.
R3: Few said that they study the data on logic, algebra and graph.

Therefore, algebra, mathematical logic, and graph theory can be considered as knowledge rather than data, at least to some extent. Therefore, logic-driven intelligence, algebra-driven intelligence, and graph-driven intelligence are knowledge intelligence without data.

The above discussion also implies that the students at a university mainly study knowledge rather than data. Therefore, the intelligence of students is, in essence, knowledge intelligence without data.

Further, Lisa likes to draw a picture from childhood on. Later she becomes a famous artist. The intelligence of Lisa is a kind of intelligence without data.

c) Experience intelligence without data

As well know, case methods are a successful instruction means for Harvard Business School (HBS) over the past century (McDonald, 2017). Many cases used at HBS are summaries of experience intelligence without data. These cases are results of integrating industry with Harvard Business School's teaching and research.

We use Q-A-R (Question-Answer-Remark) (Sun & Finnie, 2005) to differentiate the experience from knowledge as follows.

Q4: What are you learning in your school?
A4: I am learning knowledge.
R4: Few say that "I am learning experience".

Q5: Why did you visit that old doctor?
A5. Because he has profound experience in diagnosing and treating the disease that I suffered.
R5: In this case, the knowledge of the doctor in diagnosing and treating the mentioned disease is not sufficient to attract the customer (or patient) to see the doctor. This is a common sense.

Knowledge and experience are intelligent assets of human beings (Sun & Finnie, 2005). The above discussion implies that experience is more important than knowledge in some fields such as clinic and hospital.

Furthermore, the following experience is also an example (Sun & Finnie, 2007):

> If John has money, then John will fly to Beijing for a holiday tomorrow.
> However, John has not enough money.
> The consequence is that John cannot fly to Beijing tomorrow.

This example is a kind of experience-based reasoning, although this reasoning is logically invalid (Sun Z., 2017). Such experience-driven intelligence is experience intelligence without data. The four new inference rules for experience-based reasoning (Sun Z., 2017), different from traditional deduction (based on modus ponens), abduction (based on abduction rule), refutation (based on modus tollens) are also inference rules without data (Russell & Norvig, 2010) (Sun Z., 2017). Therefore, the intelligence based on these experience-based inference rules are also experience intelligence without data.

d) Wisdom intelligence without data

The exemplar for wisdom intelligence without data is the theory of relativity developed by Albert Einstein. Einstein is best known for his mass–energy equivalence formula $E = mc^2$ which has been considered "the world's most famous equation" (Bodanis, 2000).

In 1905, Einstein published four groundbreaking articles, which contributed substantially to the foundation of modern physics and changed views on space, time, mass, and energy (Wikipedia-Annus, 2020). At the time these four papers were written, Einstein did not have easy access to a complete set of scientific reference materials nor big data on physics, although he did regularly read and contribute reviews to *Annalen der Physik*. Additionally, scientific colleagues available to discuss his theories were few. The experimental confirmation of Einstein' theory of relativity could not be obtained until the time dilation experiments of Ives and Stilwell (1938) and Rossi and Hall (1941) (Wikipedia-Annus, 2020). However, Einstein received the 1921 Nobel Prize in Physics.

It is obvious that Einstein's wisdom without data and thought experiment without data had played a decisive role in writing the above-mentioned papers and his theory of relativity.

e) A Unified Example for intelligence without data

The exemplar for DIKEW intelligence without data, taking into account DIKEW intelligence, is the Art

of War, a book written by the Chinese ancient military strategist Sun Tze 2000 years ago(Giles, 2007).The book is composed of 13 chapters. Each one is devoted to a distinct aspect of warfare and how that applies to military strategy and tactics. For almost 1,500 years, the book has been the lead text in an anthology and always affected Chinese military strategies and Chinese culture. For example, every Chinese has learned in the primary school that "If you know both yourself and your enemy, you can win numerous (literally, "a hundred") battles without jeopardy," which is directly extracted from the book.

In the Art of War, there are no data but affluent information, knowledge, experience, wisdom, and intelligent methods and strategies for using information, knowledge, and experience for military battles, summarized by Sun Tzu. Therefore, this book reflects an ancient Chinese military intelligence for wisdom without data, experience without data, knowledge without data, information without data, and their integration.

VI. Discussion and Implications

Intelligence without data reflects a social reality because most people live in the environment of intelligence without data, although more and more digital citizens live in the digital age. Hate or love is related to intelligence without data. Logical thinking, algebraic systems are results of intelligence without data. All these are the motive for doing this research.

This article is also motivated by the work of R.A. Brooks on Intelligence without Representation (Brooks R. A., 1991)and Intelligence without Reason (Brooks R. A., 1991). Following the ideas of Brooks, intelligence without data can be extended to intelligence without information, intelligence without knowledge, intelligence without experience, intelligence without wisdom. Their interrelationships can be represented as a pyramid of intelligence without wisdom, as illustrated in Figure 2.

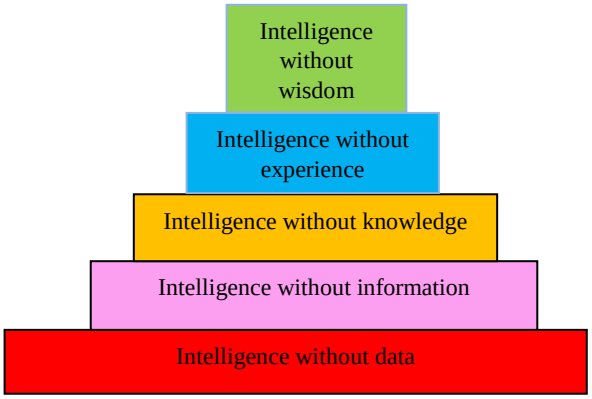

Fig. 2: A pyramid of Intelligence without wisdom

The hierarchy of data, information, knowledge, experience, and wisdom (DIKEW) is an integrated form of the results in (Sun & Finnie, 2003), (Sun & Finnie, 2005), and the DIKW (Ackoff, 1992) (Rowley, 2007) . Sun and Finnie propose a DIKED hierarchy, from data up to deception via information, knowledge and experience (Sun & Finnie, 2003). They states that from the history of modern computing, the abstraction process from data to deception requires corresponding processing technology such as data processing and knowledge processing, which further involve data reasoning, data management and knowledge reasoning, knowledge management (including intelligent agents) and experience management respectively (Sun & Finnie, 2004; 2010). The DIKEW hierarchy removes deception and keeps data, information, and experience because possessing knowledge is only one necessary condition for a field expert. The experience is more important than knowledge for a field expert to deal with tough problems (Sun & Finnie, 2005). Further, accumulation of knowledge is the necessary condition of accumulating experience for a field expert (Sun Z., 2017). Therefore, the DIKEW hierarchy is an extended form of DIKW hierarchy (Rowley, 2007) (Liew, 2013)and DIKED hierarchy (Sun & Finnie, 2003) by adding experience as a level between knowledge and wisdom.

We search Google scholar (www.scholar.google.com.au; on 29 May 2020) and find that there are round11 searched results on "Intelligence without Data," including the preprint of the author. Going into these results, "Intelligence without Data" has been used, to some extent, in the related four results are as follows: 1) Producing environmental *intelligence without data* that can be shared by multiple user communities; 2). SAP Operational Process *Intelligence without data* replication; 3). There was no intelligence without data collection, and 4). Business *intelligence without data* ware houses. It implies that there are no real researches on intelligence without data from either information systems or artificial intelligence or intelligent systems. This article provides the first attempt to explore intelligence without data.

In Section 2, we proposed DIKEW intelligence: Data intelligence, information intelligence, knowledge intelligence, experience intelligence, and wisdom intelligence. These can be considered as a natural consequence of the DIKEW hierarchy. They are also the integration between the DIKEW hierarchy and intelligence or the result of the integrated framework of intelligence. Each of them has drawn some attention to some extent in computing and related discipline, based on the searched results using Google Web, Google Scholar (Retrieved on 29May 2020),and SCOPUS (Retrieved on 29 May 2020), illustrated in Table 2.

Table 2: DIKEW intelligence and their references

DIKEW intelligence	Google Web (x)	Google scholar (y)	SCOPUS (z) in 2017	Item of DIKEW on Google Scholar (m)
Data intelligence	2,100,000	13,100	23	Data 10,400,000
Information intelligence	411,000	31,100	26	Information 7,750,000
Knowledgeintelligence	271,000	11,100	15	Knowledge 5,860,000
Experience intelligence	121,000	4,220	4	Experience 5,850,000
Wisdom intelligence	254,000	4,550	3	Wisdom 2,930,000

In Table 2, Google web (https://www.google.com.au/?gws_rd=ssl) and Google Scholar (https://scholar.google.com.au) are used to search each of DIKEW intelligence. The researched results are listed in each cell of the second and third columns. For example, there are about 2,100,000results from Google Web and about 13,100 results from Google Scholar when searching "data intelligence" (on 29May 2020). SCOPUS is also used to search "article title" containing every item of DIKEW intelligence, and its searched number of articles (z). The rightest column is the searched number of articles containing every item of DIKEW using Google Scholar, for example, the searched number of articles containing wisdom is 2,930,000. From the searched results based on SCOPUS, we can find that data, information, knowledge, and experience have drawn lasting attention in academia, in contrast, wisdom seems not easy to be studied towards scientific publications (McDonald, 2017).

As shown in Table 2, data intelligence, information intelligence, and knowledge intelligence have drawn significant attention in the general community (Google Web search) and increasing attention in the scholarly community (Google Scholar and SCOPUS). For example, Hauch, et al, have received some results on information intelligence (Hauch, Miller, & Cardwell, 2005). However, there are few genuinely scholarly publications on experience intelligence and wisdom intelligence in Google Scholar and SCOPUS at the moment, although there are several searched results. For example, experience intelligence can explore the value of experience data (Blake-Plock, 2017), big data intelligence and experience intelligence have also drawn some attention (Blake-Plock, 2017) . Therefore, there is a big space for developing information intelligence, knowledge intelligence, experience intelligence, and wisdom intelligence as a part of DIKEW intelligence.

VII. Conclusion

This article extended the DIKW hierarchy to DIKEW hierarchy consisting of data, information, knowledge, experience and wisdom and proposed a novel perspective on data intelligence, information intelligence, knowledge intelligence, experience intelligence and wisdom intelligence. It demonstrated that intelligence without data consists of information intelligence without data, knowledge intelligence without data, experience intelligence without data, and wisdom intelligence without data based on the proposed DIKEW hierarchy and intelligence and wisdom algebra. Intelligence without data has not drawn much attention in AI and machine learning. It argued that big data should incorporate intelligence without data to serve the world; at the same time, intelligence without data can enhance human intelligence and artificial intelligence. The proposed approach in this article might facilitate research and development of big data analytics, AI, machine learning, and business intelligence as well as intelligent agents.

In the future work, we will illustrate the DIKEW hierarchy and intelligence with cases extracted from the real world. We will delve into the proposed intelligence without data with more references. We will explore intelligence without information, intelligence without knowledge, intelligence without experience, intelligence without wisdom, and their interrelationships.

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Robustness Algorithms for the Airport Gate Assignment Problem

By Amadeo Ascó Signes
University of Nottingham

Abstract- Assigning commercial flights to available airport gates can have a major impact on the efficiency of flight schedules as well as on the level of passenger satisfaction with the service. These assignments also depend on the service requirements of flights and the capacity of stand facilities. Unexpected changes also called perturbations, like those due to air traffic delays, severe weather conditions, or equipment failures, may disrupt the initial assignments and increase the difficulty of maintaining smooth operations, which will detrimentally affect customer satisfaction.

The provision of solutions which reduce the potential detrimental effect of perturbations in the stands already assigned on the day of operation is desirable and some approaches are presented here, and compare between them to help identify their performance and trends.

Keywords: robustness, airport gate assignment problem, scheduling, heuristics, evolutionary algorithms.

GJCST-C Classification: F.2.2

Strictly as per the compliance and regulations of:

Robustness Algorithms for the Airport Gate Assignment Problem

Amadeo Ascó Signes

Abstract- Assigning commercial flights to available airport gates can have a major impact on the efficiency of flight schedules as well as on the level of passenger satisfaction with the service. These assignments also depend on the service requirements of flights and the capacity of stand facilities. Unexpected changes also called perturbations, like those due to air traffic delays, severe weather conditions, or equipment failures, may disrupt the initial assignments and increase the difficulty of maintaining smooth operations, which will detrimentally affect customer satisfaction.

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I. Introduction

Aircraft depart from an airport and arrive at their destination airport, from which the aircraft may again depart to yet another airport, and this may be repeated many times a day for each aircraft. During the time between arrival and departure, while the aircraft is still at the airport, it needs to have a space allocated at a stand on the airport airside, where some operations may need to be performed before it is ready to continue its cycle of departure and arrival. The stands next to the airport gates are scarce and expensive resources which must be used efficiently and be assigned to aircraft effectively. The gate assigned to an aircraft arrival may not be the same as that assigned to the same aircraft for departure, and the intermediate parking operation if any is required, between arrival and departure assignments may also be at a different stand, Figure 1.

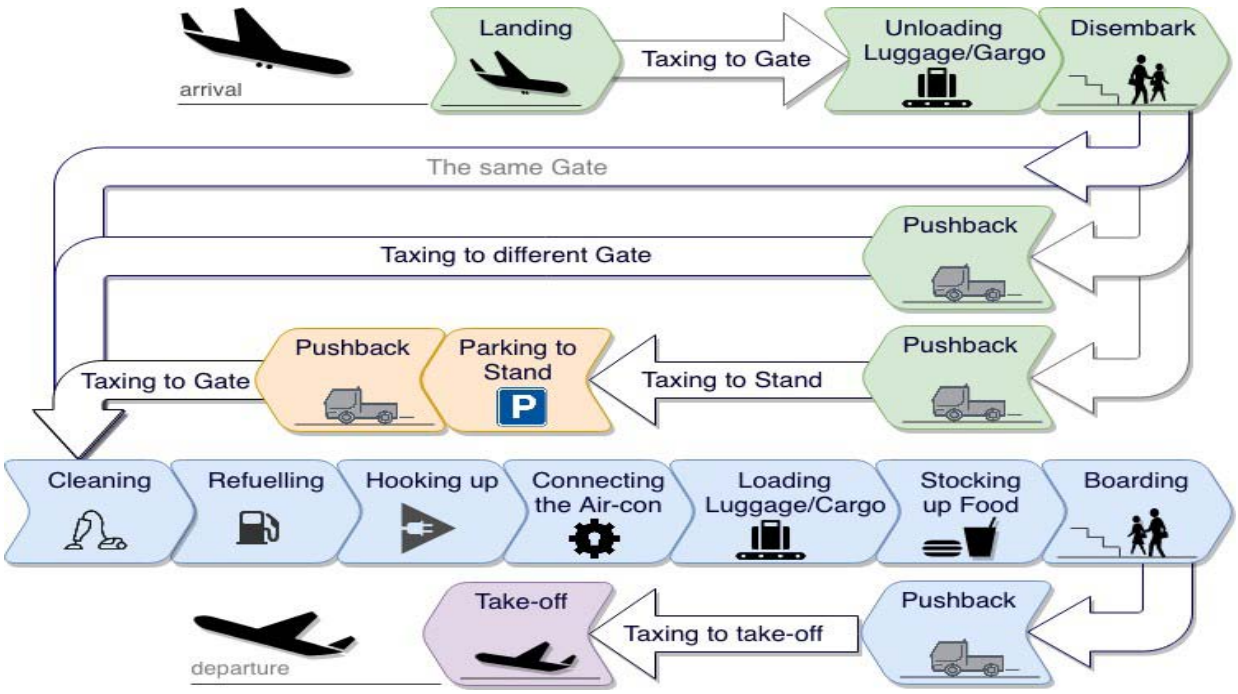

Fig. 1: Simplified overall process of an aircraft in an airport

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The Airport Gate Assignment Problem (AGAP) relates to the assignment of stands to flights already scheduled. The flights have a scheduled arrival and departure time, between which the aircraft is located on either one or several stands sequentially. The movement of an aircraft between stands normally requires the use of tugs (towing trucks) which add extra cost to the aircraft's operations, which airlines would prefer to avoid whenever possible. When an aircraft is assigned to different stands in the same arrival/departure period, to disembark passengers from one stand and embark them on another, then the aircraft must be moved from its assigned stand to the stand assigned to it next until it is located on the stand assigned for its departure. This operation may be executed either by using the aircraft's engines or by tugs, Figure 2.

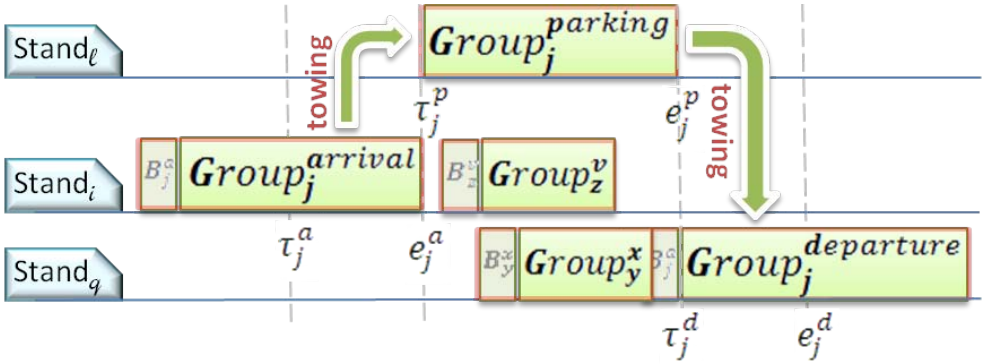


Fig. 2: Assignment of flights to stands when towing is required

With the increase in passenger traffic volumes and number of flights, the complexity of this task and the number of factors to be considered have increased significantly, and efficient gate utilization has received considerable attention in passed years, e.g. Ascó (2019), Kim and Feron (2013), Seker and Noyan (2012), Jaehn (2010), Li(2009), Hu and Di Paolo (2007). AGenetic Algorithm (GA) was used by Lim et al (2005) and Ghazouani et al (2015).

The provision of solutions which reduce the potential detrimental effect of perturbations in the resources already assigned on the day of operation is desirable and was previously studied for the Airport Baggage Sorting Station Assignment Problem (ABSSAP) by Ascó (2016, 2013), and it was studied for the AGAP by van Schaijk and Visser (2017), Ascó (2013), Yan and Tang (2007). But this is achieved at the expense of the optimality, although this is far from easy, as the perturbations are not known in advance. It would also be advantageous if the disrupted assignments have no knock on effect, or if any, only a minor one.

A flight is said to be in conflict if the departure time of the flight is greater than the arrival time of the next flight at a gate. Reassigning conflicting flights caused by flight delays is one of the major daily tasks for the airport scheduling team. When a delayed flight affects the flight schedule of the subsequent flight then there are two ways it may be corrected: either to reassign the conflicting flight or else reassign the subsequent flight to the conflicting one. A situation may arise when reassigning conflicting flights or the subsequent flight to another gate, where the reassigned flight is interfering with the subsequent flight at the new gate. Thus some reassignments may, therefore, have a downstream effect on the overall schedule, producing more conflicting flights requiring further reassignments, and potentially increasing the difficulty of the problem at a later stage.

The model used for the AGAP is based on that proposed in Dorndorf (2002), which considers the problem as a resource constrained project scheduling problem, originally presented in Dorndorf et al (2000), used in Ascó (2013) Chapter 7 and 8 with the Steady State Evolutionary Algorithm (SSEA), and Ascó (2019). The robustness approaches presented and studied for the ABSSAP by Ascó (2016) are adapted to the AGAP and are next presented and studied with an adapted implementation of the SSEA for the AGAP.

II. Robustness Approaches

The approaches considered here take account of the potential disruptions on the day of operation, and are: Total Reduction in Service Time (TRS), Area of Reduction in Service (ARS), Sub-Area of Reduction in Service (SARS), Unsupervised Estimated Stochastic Reduction in Service (UESRS), Reduction in the Number of Conflicts (RNC) and Probability of Conflict Based on the Gap (PCBG), which are described below and more details can be found in Ascó (2016), and Ascó et al (2013).

a) Total Reduction in Service

Mangoubi and Mathaisel (1985) proposed the use of 'buffer times' between two flights which are consecutively assigned to the same gate in order to obtain robust assignments, defining the reduction in service as that part of buffer time which overlaps with the previous assignment to the same gate. Given the detrimental effects that the reduction in service time has

on the robustness of the assignment as against reallife delays, it is advisable to minimise the total reduction in service time, thus maximising buffer times.

The arrival and departure flights correspond to the arrival and departure activities respectively. The time between the scheduled arrival time at the stand and the time at which the flight is scheduled to leave is called the base service duration. A predefined period of time, called buffer time, the value of which depends on the flight, is preappended to the flight base starting service time, so that such buffer time may be reduced to allow other assignments to be placed before this flight, but the base service duration must not be affected, Figure 3. The use of buffer service time implies a preference for a greater predetermined service time for each flight, and this buffer time may be obtained from historical information. A reduction in the buffer time for the arrival and departure of aircraft *j* has been named r_j^a and r_j^d respectively, and the sum of these constitutes the reduction in service cost, so this objective can be expressed as $-\sum_{j=1}^{M}\sum_{x}^{a,d} r_j^x * \sum_{i=1}^{N} y_{ij}^x$ where y_{ij}^x is one if flight *j* is assigned to activity *i* for activity *x* (arrival, parking, or departure), or zero if flight *j* is not assigned to stand *i* during activity *x*.

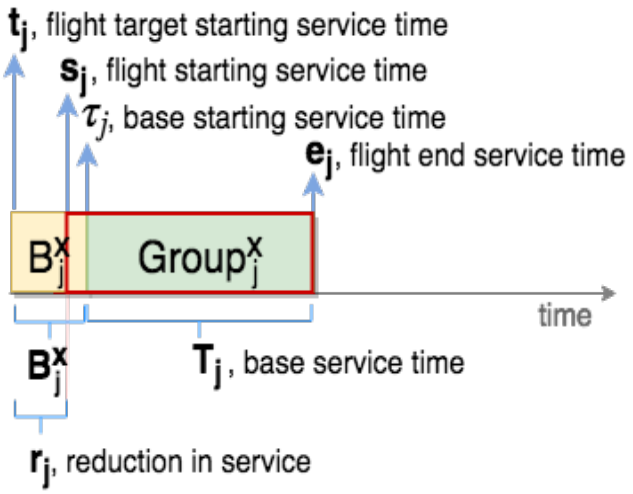


Fig. 3: Overview of the flight times

If the remote parking activity is assigned to the same stand as the departure activity, then the reduction in service for the departure flight is zero. This is a consequence of both activities referring to the same aircraft.

b) Distribute Idle Time

Different approaches aim to spread the time between the end of one assignment and the start of the next one at the same gate. This time is normally called 'idle time'. This may be achieved by using a penalty function, such as the arctangent function. Bolat (1999) proposed the distribution of 'idle time' uniformly amongst gates.

A disadvantage of this approach and many others, i.e. UESRS, PCBG and RNC, is that they normally treat all assignments equally, whereas disturbance of a schedule is more likely to have disruptive consequences for the assignment at the time of day when service flight density is greater, which is taken into account by the next two approaches.

c) Area Reduction in Service

The effect of service reduction is not the same throughout the day, but depends on the time of day. It is more likely that disruptions will occur during periods when the flight density is higher than when fewer flights require servicing, i.e. delay during high flight density is more likely to propagate given that less resources will be available to absorb any reassignment without repercussions on other flights. At the same time, it is these cases where it is most difficult to keep a sufficiently large gap between assignments to the same Airport Gate (gate).

Lower Maximum Assignment Point with Parking (LMAPp) is the number of resources required to service a certain number of activities (full assignment is achievable for any other higher number of gates for the same number of flights) when the service starting time (s_j) coincides with the target starting service time (t_j), which it is an adaptation for the AGAP of the Lower Maximum Assignment Point (LMAP) initially introduced in Ascó et al (2013) for the ABSSAP.

Upper Maximum Assignment Point with Parking ($UMAP_p$) is the number of resources required to service those activities when the service starting time (s_j) coincides with the base starting service time (τ_j), which it is an adaptation for the AGAP of the Upper Maximum Assignment Point (UMAP) initially introduced in Ascó et al (2013) for the ABSSAP. When considering the extra constrain of parking it may potentially be required extra resources to service the same number of flights in comparison to when there is not parking to consider.

The effect of assigning two activities to the same stand, namely too close to each other, has a more detrimental effect in circumstances where there are fewer gates able to accommodate flights. An indication of gate availability on time is provided by the activity density distribution, where no reduction in the target service start time is allowed, see Figure 4. To take account of this, use is made of the area between the reduced service time of the flight density distribution function divided by the Average Assignment Point (AAP) as presented in Ascó (2016, 2013).

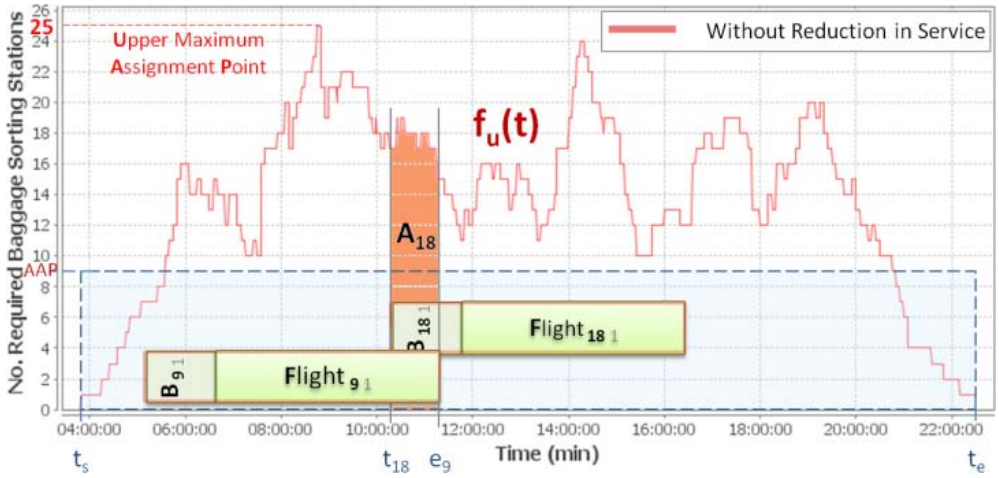


Fig. 4: Distribution of flights over time and Area Reduction in Service Objective, A_{18}

$$AAP = \frac{\int_{t_s}^{t_e} f_u(t)\ dt}{t_e - t_s} \qquad (1)$$

Aj is the density distribution area for the time period from the target service time of flight *j* (t_j) to the end of service time for the previous flight assigned to the same gate, for example in Figure 4, $A_{18} = \int_{t_{18}}^{e_9} f_u(t)\ dt$. AAP_j is here defined as the mean number of flights over the target start time for flight *j*, t_{18}, and the end of service time for the previous flight assigned to the same gate as flight *j*, e_9, Equation 1.

d) Sub-Area Reduction in Service

This is based on the same principle as the ARS, but uses the two activity density distributions, firstly where no buffer time is used and secondly when the full buffer time is used (buffer time may not be reduced). The cost is that area between both distributions divided by a factor, Figure 5. The factor was estimated to be equal to the UMAP less the LMAP, which cannot be used if both have the same value, that is to say, LMAP equal to UMAP. To avoid this predicament the un-factored subarea is taken, i.e. using the sub-area itself. This will be the approach considered here, as known as known as Base Sub-Area Reduction in Service (BSARS), Equation 2.

$$A' = \int_{t_s}^{t_e} (f_u(t) - f_l(t))\ dt \qquad (2)$$

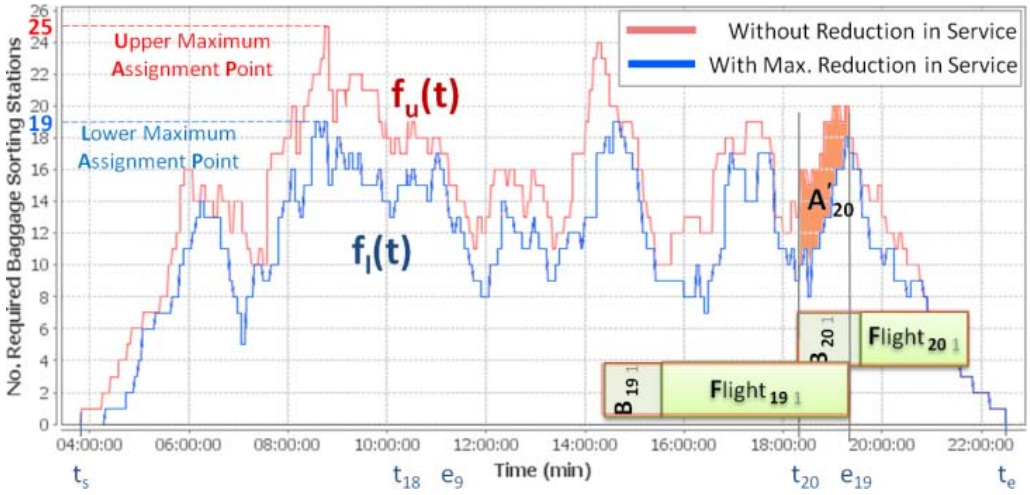


Fig. 5: Sub-Area Reduction in Service Objective, A_{20}

e) Reduction in the Number of Conflicts

A similar approach was used in Yan and Tang (2007) where random delay scenarios are generated in the 'Planning Stage' which are used to account for the potential disruptions in the schedule on the day of implementation by means of calculating the expected semi deviation risk measure (Ruszczynski and Shapiro (2003)) for all those delay scenarios.

The Reduction in the Number of Conflicts (RNC) is a stochastic approach which uses perturbed schedules to account for the conflict potential in consequence of schedule perturbations on the day of execution.

This approach is based on reducing the number of conflicts on the day of operation. Given that the real perturbed conditions will not be available until the day

the schedule is implemented, these perturbed conditions are simulated by examining a set of perturbed base cases, *S*, which may be obtained in different ways, such as randomly, e.g. from historical data or calculated using known distribution(s) from information available at the time of generating the assignments.

Considering a set of perturbed schedules *S*, which simulate the perturbations on the day of operation. A new variable is introduced c_{js}, which for a given solution of assignments has the value 1 if flight *j* is in conflict with another flight in the perturbed schedule $s \epsilon S$, or zero otherwise. The average number of conflicts in the set of perturbed schedules *S* is calculated by Equation 3, which is a measure of the solution robustness.

$$f_2 = \frac{-1}{|S|} * \sum_{s \epsilon S} \sum_{j=1}^{m} c_{js} \qquad (3)$$

When reassigning conflicting flights or subsequent flights to other gates, a situation can arise where the reassigned flight interferes with the subsequent flight at the new gate, a socalled secondary conflict. Some reassignment may therefore have a downstream effect on the overall schedule, producing more conflicting flights, in turn requiring further reassignments, thus potentially increasing the difficulty of the problem later on.

The above version considers all the conflicts to be of the same importance, but it is preferable to have conflicts which do not have repercussions later, that is, can be reassigned to another gate without affecting any of the assignments already in existence. To account for this situation a new variable c_{js} is defined which takes the value 1 if the reassignment of conflicting flight *j* in a perturbed schedule 's' affects other assignments already in existence, or zero otherwise. The objective is presented as Equation4where the constant, α, $0 \leq \alpha \leq 1$, denotes the importance of the conflicting flight repercussions on other assignments; $\alpha = 0$ corresponds to the case where no account is taken of any repercussion on other assignments, which corresponds in turn to Equation 3, and $\alpha = 1$ corresponds to the cases in which both the conflicting flights and their repercussions on other assignments are considered to be of the same importance. An $\alpha > 1$ refers to the cases where more importance is given to the repercussions of a conflict on assignments other than the conflict itself.

$$f_2 = \frac{-1}{|S|} * \left(\sum_{s \epsilon S} \sum_{j=1}^{m} (c_{js} + \alpha * c'_{js}) \right) \qquad (4)$$

Calculation of the conflicts is time consuming, and even more so if the effect of the conflict repercussions is also calculated, which is further aggravated by the need to use a large number of schedules in the perturbed set *S* in order to achieve a good representation of all the potential situations. The execution time is one of the disadvantages of using this approach.

f) Probability of Conflicts Based on the Gap

The previous approach would normally require a large number of perturbed data sets, which makes its application very slow. Given that we are still interested in reducing the number of conflicts, but without the heavy cost in speed imposed by the RNC approach, then the probability of having a conflict in a given 'idle time' is used for each flight. This can be easily obtained if the delay distribution is known. In the case of a normal folded distribution (no negative numbers and with zero mean) and independent delays for flights, the probability of a conflict for different standard deviations is shown in Figure 6. This could also be extended to other distributions and to non-zero means.

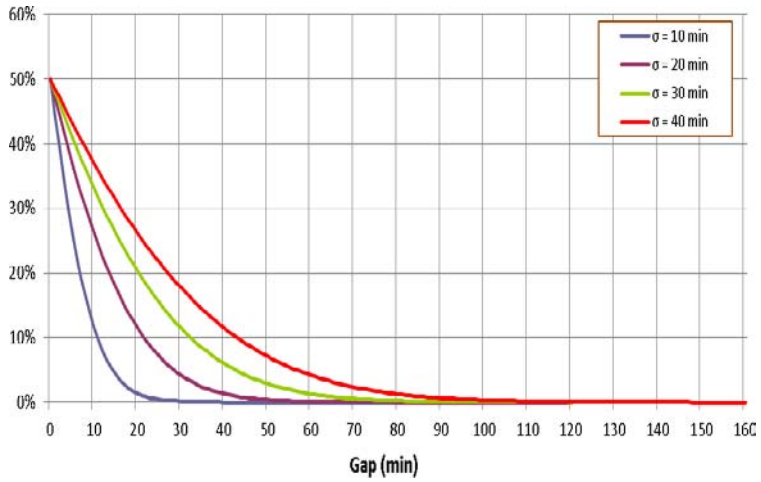


Fig. 6: The probability of a conflict for two consecutive flights assigned to the same gate based on the intervening gap modeled with Folded Normal distributions of a zero mean and standard deviation σ.

The PCBG is another stochastic approach which uses the predicted delay in activities probability distribution functions to anticipate the delay and take account of it in the assignments. In the case of a normal folded distribution (no negative numbers and with zero mean) and independent delays for flights, the probability of a conflict for different standard deviations.

Independent delays are considered initially, where a conflict between two consecutive flights is independent of other flights assigned to the same gate. The assignments to different gates are independent from the point of view of conflicts. The probability of two consecutive flights having overlapping service times (a conflict), corresponds to the sum of the product between the probability of a sufficiently large delay on the part of the previous flight assigned to that gate, and the probability of the next consecutive assignment to the same gate not being sufficiently delayed, as shown in Figure 7, where $\eta_j(t)$ is the probability density function for flight j and $t_0 = \tau_k - e_j$.

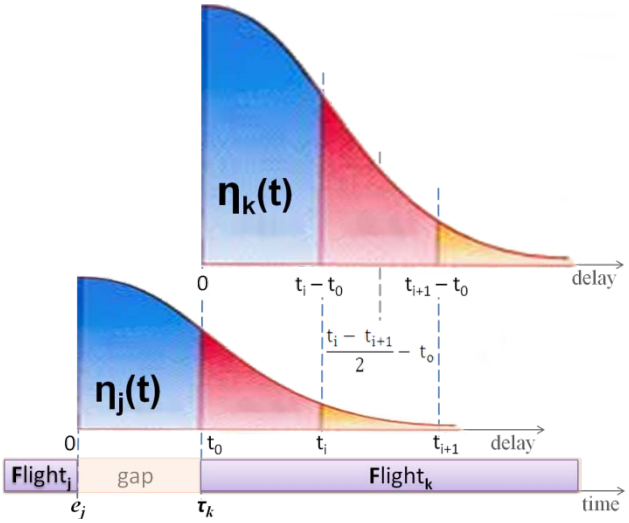


Fig. 7: Probability of a conflict between two consecutive flights based on the intervening gap

g) Unsupervised Estimated Stochastic Reduction in Service

Lim and Wang (2005) proposed a stochastic programming model for the AGAP with a robustness cost of conflicts, which is estimated by a function, *v(j, k)*. Flights are ordered by their base starting service time, so the gap between two flights *j* and *k*, *l(j, k)*, assigned to the same gate, where $j < k$ and *j*, $k \in [1 \ldots M]$, is the difference between flight *k*'s target service time and the prior assigned flight *j*'s end service time, Equation 5, where $l(j,k) = -r$ for $l(j,k) < 0$, as shown in Figure 8. $v(j,k)$ is used to estimate the mean conflict probability between flights *j* and *k* assigned to the same gate, which is a function of the gap *l(j, k)*, where larger gaps between assignments to the same gates result in lesser probability of real flight conflicts. $v(j,k)$ is normalised in Equation 6.

$$l(j,k) = t_k - e_j \quad (t_k = \tau_k - B_k) \tag{5}$$

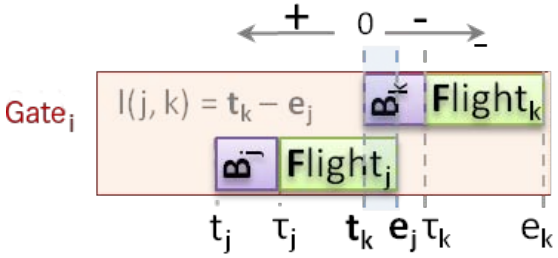


Fig. 8: Overlap between two flights *j* and *k* assigned to the same gate

$$E(p(j,k)) = \sum_{i=1}^{N} \left(y_{ij} * y_{ik} * \frac{v(j,k) - v_{min}(j,k)}{v_{max}(j,k) - v_{min}(j,k)} \right) \tag{6}$$

$$f_2 = - \sum_{j=1}^{M-1} \sum_{k=j+1}^{M} E(p(j,k)) \tag{7}$$

The definition of *v(j, k)* comes from the application domain, in the absence of historical data; some unsupervised estimation functions were introduced in Lim and Wang (2005). Figure 9 shows the penalty (y-axis) incurred for different unsupervised estimation functions as a function of the gap (x-axis). Negative values refer to reductions in service time between two assignments to the same baggage sorting

station (BSS), which are heavily penalised as they may require reassignment should delays occur, whereas positive gaps are penalised less. Wider gaps between two assignments reduce the need to reassign delayed flights, given that the delay has to be larger than the gap in order to affect the following assignment to the same BSS. Similarly, to start the service earlier may not require the flight to be reassigned because the duration of earliness has to be lower than the gap in order to affect the previous assignment. Both earliness and delay probabilities decrease as the gap increases. Sufficiently large gaps may also be used on the day of operation by disrupted flights which need to be reassigned, such that the detrimental effect of disruptions on that day is reduced.

The unsupervised estimation functions introduced in Lim and Wang (2005) are presented below and are shown in Figure 9:

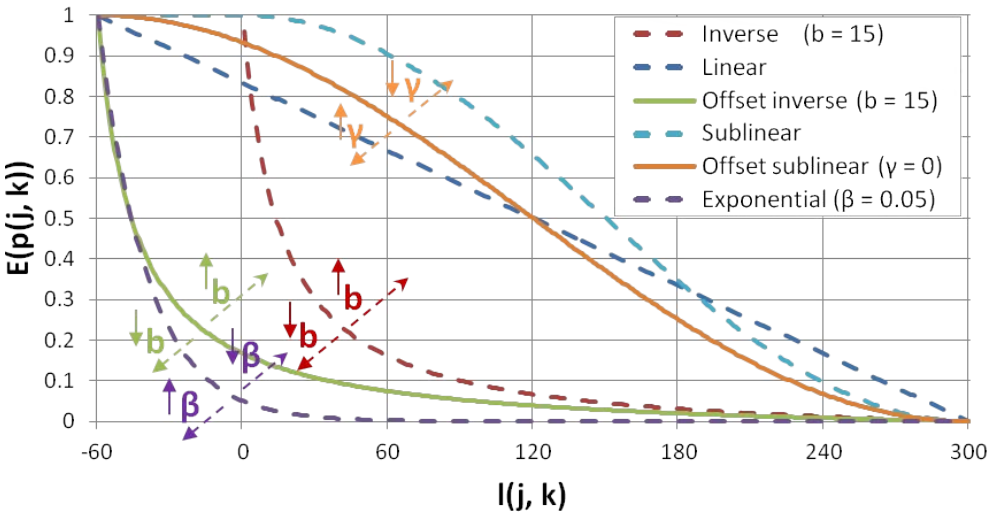


Fig. 9: Penalty for different unsupervised estimation functions based on the gap between assignments

1. Linear estimation:

$$v(j,k) = -l(j,k) \tag{8}$$

2. Exponential estimation:

$$v(j,k) = e^{-\beta * l(j,k)} \tag{9}$$

3. Inverse estimation

$$v(j,k) = \begin{cases} \frac{b}{l(j,k)+b} & \text{if } l(j,k) > 0 \\ 1 & \text{otherwise} \end{cases} \tag{10}$$

The value of the constant '*b*' changes the penalization as shown in Figure 9, so a higher '*b*' increases the penalisation and a lower '*b*' decreases it. An appropriate value should be selected to properly weight the influence of the potential conflicts. Lim and Wang (2005) used $b = 15$ minutes, which proved to provide rather poor results when compared with the exponential estimation function, which may partly be caused by the fixed cost when $l(j, k) < 0$ (dark red dash line, Figure 9), whereas in the exponential estimation function (purple dash line, Figure 9) this is not the case. The value used for 'b' may be too great, and a lower value would make this estimation function provides values closer to those provided by the exponential estimation function which provided fitter solutions in the results presented by Lim and Wang (2005). Consequently, a value $b = 6$ was seen in the experiments studied for the ABSSAP in Ascó (2016) to provide better results than when $b = 15$. In general an even lower value did appear to perform better in some instances but not as well as $b = 6$, as shown in Ascó (2016).

The inverse estimation function as considered by Lim and Wang (2005) treats all gaps smaller than the buffer time equally, which does not represent a real case since smaller gaps between flights are more likely to result in conflicts than larger ones on the day of operation. Given this, and that the exponential estimation function performs best and treats all gaps differently, it is proposed that all of the gaps be treated differently, as shown by the modified version which is herein named 'Offset inverse', Equation 11, which is shown in Figure 9 for $b = 15$ (green line).

$$v(j,k) = \frac{b}{l(j,k) - \min\{l(j,k)\} + b} \tag{11}$$

4. Sublinear estimation:

$$v(j,k) = \begin{cases} \cos\left(\frac{\pi * l(j,k)}{l_{max}}\right) & \text{if } l(j,k) > 0 \\ 1 & \text{otherwise} \end{cases} \tag{12}$$

This estimation also suffers from the same problem as the Inverse estimation, and may be improved by offsetting its value so that the maximum penalization corresponds to l_{max} and the minimum to l_{min}, Equation 13, which is shown in Figure 9 for $\gamma = 0$.

$$v(j,k) = \cos\left(\frac{\pi * (l(j,k) - l_{min} + \gamma)}{l_{max} - l_{min} + \gamma}\right) \tag{13}$$

The gap definition used takes account of the buffer time, as the target service duration is the base service duration (T_k) plus the buffer time (B_k) for the flight. This makes the estimation functions dependent on the buffer time of each flight, as shown in Figure10for two buffer times of 30 min and 15 min each. When the buffer time is the same irrespective of the flights, $B_k = B \forall k \in [1 \ldots M]$, as considered in Lim and Wang (2005), the cost is the same irrespective of the flight, depending only on the separation between consecutive flight assignments, but this is not the situation when the buffer time depends on the flight, namely long, medium or short distance flights, which are the cases studied here.

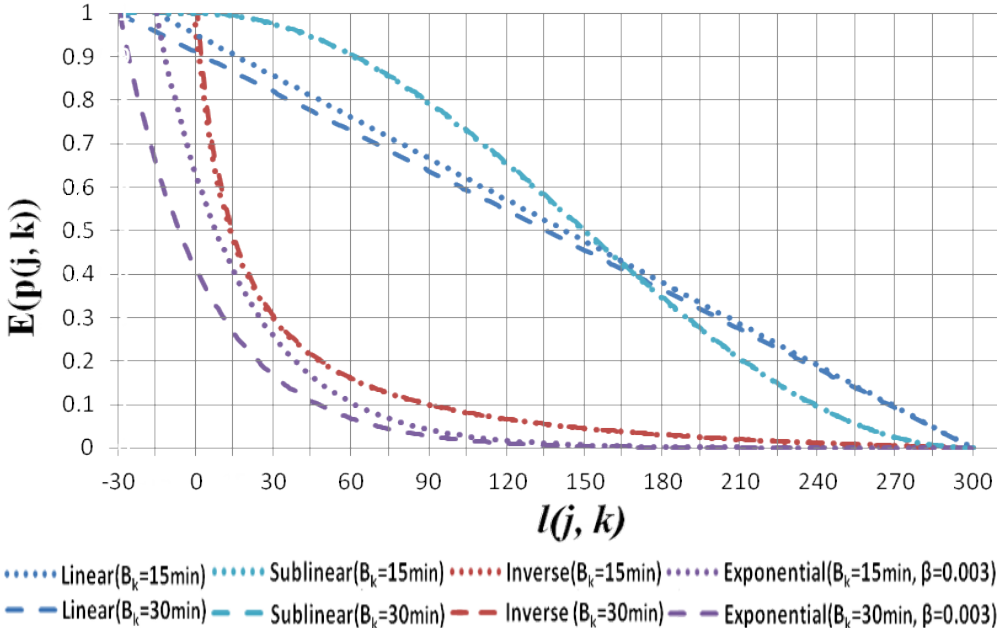


Fig. 10: Penalty for different unsupervised estimation functions based on the gap between assignments for different buffer times

To penalise all of the flights similarly it is necessary to adapt the previous estimation formulas for $v_{j,k}$ as follow:

1. Inverse:

$$v(j,k) = \frac{b}{l(j,k) + B_k + b} \tag{14}$$

2. Sub-linear:

$$v(j,k) = \cos\left(\frac{\pi * (l(j,k) + B_k + \gamma)}{l_{max} + D_k + \gamma}\right) \tag{15}$$

In addition in the case of the two consecutive flights *j* and *k* the max $\{v(j,k)\}$ corresponds to the *v(j, k)* for min$\{l(i,k)\} = -B_k$.

III. Data

A week of records of flight assignments to stands was provided by London Heathrow airport for terminal four, composed of schedules from the 6th to the 12th September 2010 (H4T1009dd). Some details are shown in Table 2, which were generated from the data supplied. Using the data summarised in Table 2, tables were generated showing the preferences of each airline, and these were used in the 'Maximise Airline Preferences' objective, shown in Section 3.1. Also, a table was generated showing the preferences of each handler, which is used in the 'Maximise Handler Preferences' objective, shown in Section 3.2.

i. *Airlines Gate Preferences*

The following is the data collected from 1st September 2011 to 31st August 2012, which it was provided by Heathrow Airport Limited (HAL), and a summary of the data is shown on Table 1.

Figure 11 shows the overall number of flights assigned to each gate, to each airline for the period from 6th September 2010 to 12th September 2010 for London Heathrow airport Terminal 4.

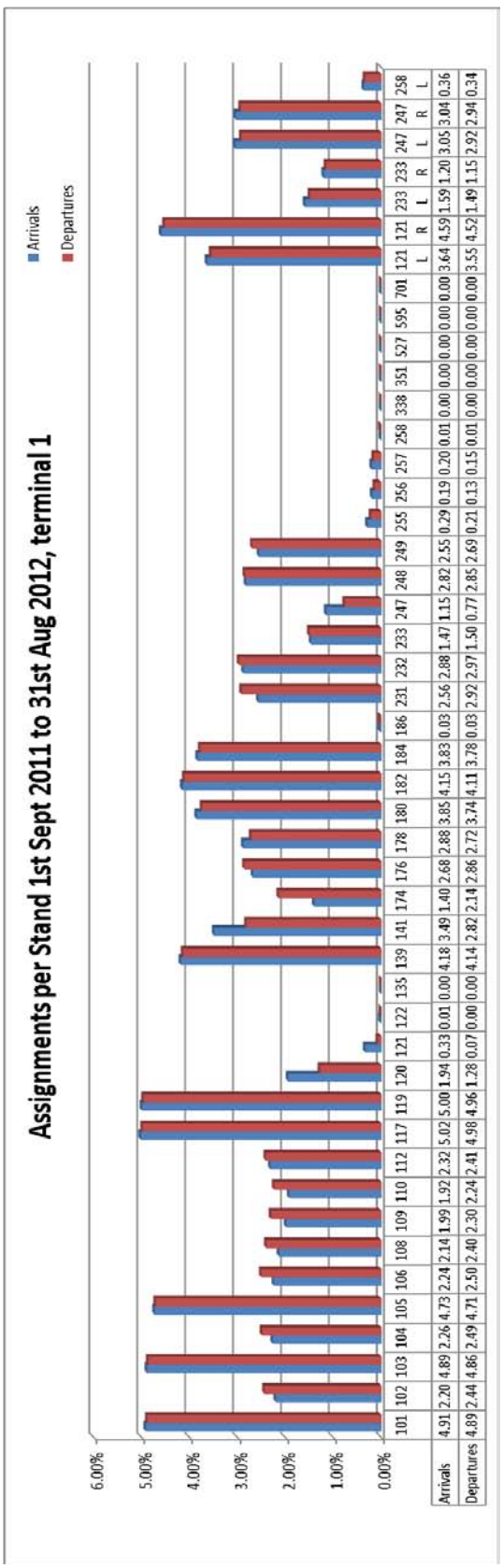
ii. *Handlers Gate Preferences*

Figure 12 shows the overall number of flights assigned to each gate, to each handler for the period from 6th September 2009 to 12th September 2009 for London Heathrow airport Terminal 4.

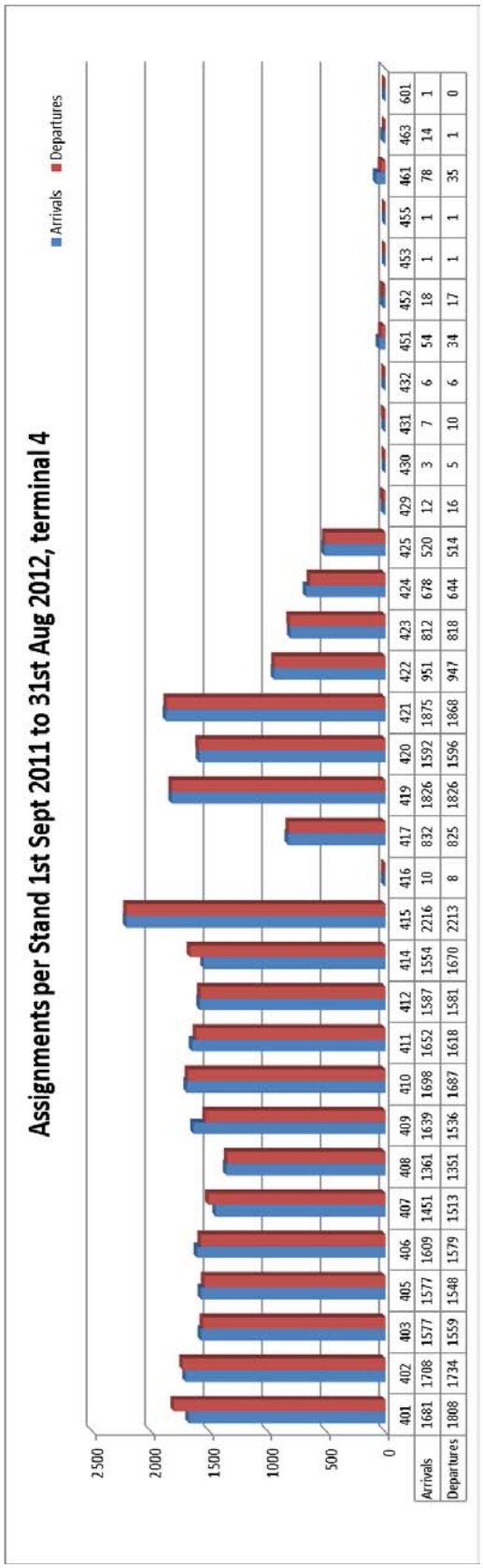
IV. Robustness Results

In this section, some experiments are conducted using the robustness approaches summarised in Section 2 for the respective weights shown in Table 3 using the SSEA previously presented in Ascó (2013), Ascó (2018).

Table 1: Assignments per stand for the period from 1st September 2011 to 31st August 2012.



	101	102	103	104	105	106	108	109	110	112	117	119	120	121	122	135	139	141	174	176	178	180	182	184	186	231	232	233	247	248	249	255	256	257	258	338	351	527	595	701	121 L	121 R	233 L	233 R	247 L	247 R	258 L	258 R
Arrivals	4.91	2.20	4.89	2.26	4.73	2.24	2.14	1.99	1.92	2.32	5.02	5.00	1.94	0.33	0.01	0.00	4.18	3.49	1.40	2.68	2.88	3.85	4.15	3.83	0.03	2.56	2.88	1.47	1.15	2.82	2.55	0.29	0.19	0.20	0.01	0.00	0.00	0.00	0.00	0.00	3.64	4.59	1.59	1.20	3.05	3.04	0.36
Departures	4.89	2.44	4.86	2.49	4.71	2.50	2.40	2.30	2.24	2.41	4.98	4.96	1.28	0.07	0.00	0.00	4.14	2.82	2.14	2.86	2.72	3.74	4.11	3.78	0.03	2.92	2.97	1.50	0.77	2.85	2.69	0.21	0.13	0.15	0.01	0.00	0.00	0.00	0.00	0.00	3.55	4.52	1.49	1.15	2.92	2.94	0.34



	401	402	403	405	406	407	408	409	410	411	412	414	415	416	417	419	420	421	422	423	424	425	429	430	431	432	451	452	453	455	461	463	601
Arrivals	1681	1708	1577	1577	1609	1451	1361	1639	1698	1652	1587	1554	2216	10	832	1826	1592	1875	951	812	678	520	12	3	7	6	54	18	1	1	78	14	1
Departures	1808	1734	1559	1548	1579	1513	1351	1536	1687	1618	1581	1670	2213	8	825	1826	1596	1868	947	818	644	514	16	5	10	6	34	17	1	1	35	1	0

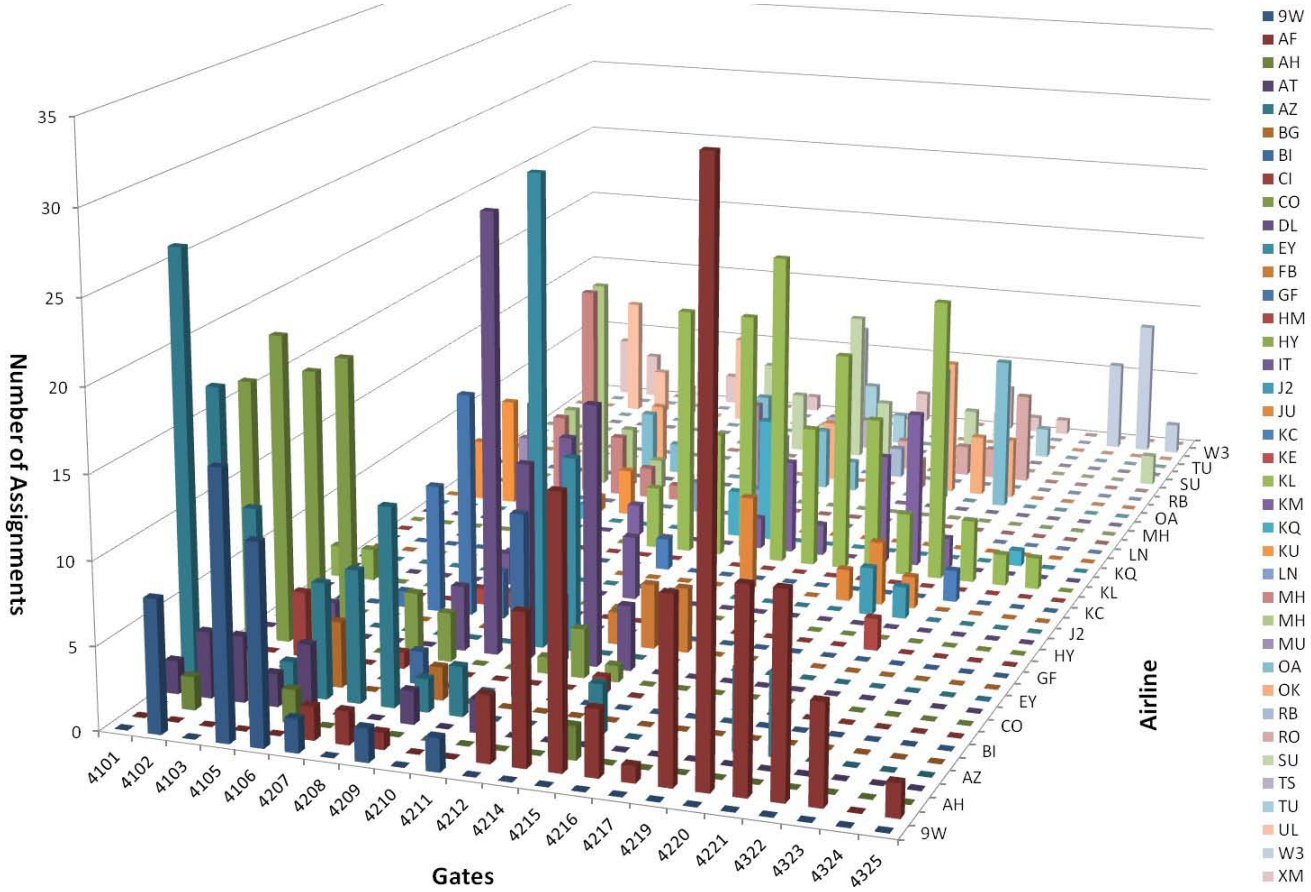


Fig. 11: Airlines preference at London Heathrow airport Terminal 4

Table 2: Data set information provided by HAL for London Heathrow airport Terminal 4.

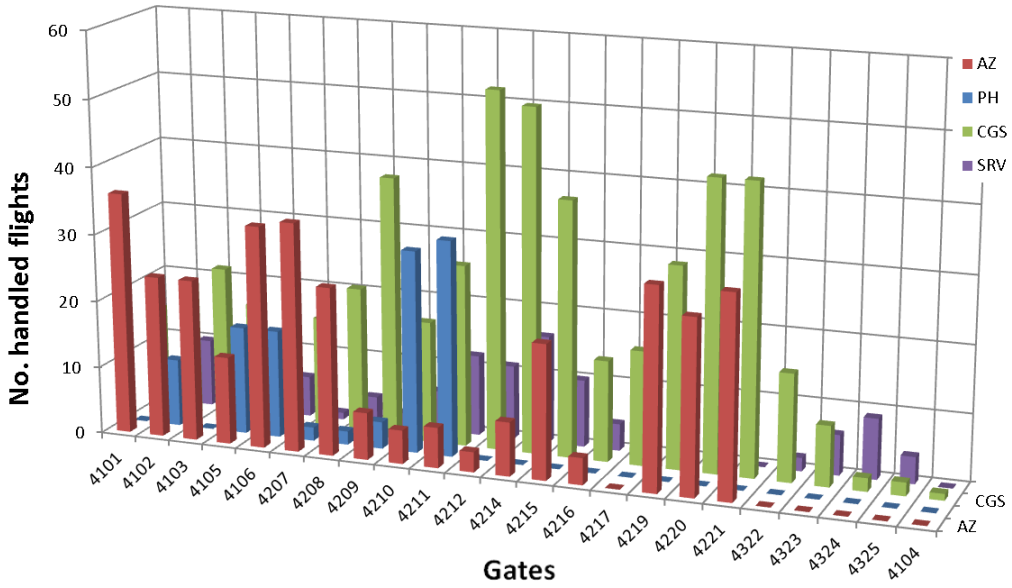
ID	Date	LMAP	UMAP	LMAPp	UMAPp	No. Activities	No. Parking Activities
H4T100906	6 Sept 2010	8	10	17	19	118	15
H4T100907	7 Sept 2010	11	14	18	20	120	15
H4T100908	8 Sept 2010	7	10	16	18	119	16
H4T100909	9 Sept 2010	8	10	18	20	119	15
H4T100910	10 Sept 2010	9	12	15	18	120	15
H4T100911	11 Sept 2010	9	10	16	16	110	11
H4T100912	12 Sept 2010	11	11	18	19	117	15

Table 3: Weights for the different robustness approaches considered with SSEA1.

Approach	Weight	Parameters Name	Values
ARS	0.00025	Buffer Time	15 min long-haul and 10 min others
ATRS	0.00025	Buffer Time	15 min long-haul and 10 min others
BSARS	0.00025	Buffer Time	15 min long-haul and 10 min others
PCBG	0.225 and 0.3125	Std. deviation	10, 20 and 30 min
TRS	0.00025	Buffer Time	15 min long-haul and 10 min others
UESRS	0.225 and 0.3125	Estimator	Exp 0.03, Exp 0.05, Inverse 6, Inverse 15, Linear, Offset Inverse 6, Offset Inverse 15, Offset-Sub linear 0, Offset Sub linear 1000 and Sub linear
		Buffer Time	15 min long-haul and 10 min others

These weights are smaller than the weights used in the ABSSAP because they have been normalised, Equation 16.

$$\sqrt{W_1^2 + W_2^2 + W_3^2 + W_4^2 + W_5^2} = 1 \quad (16)$$



	4101	4102	4103	4105	4106	4207	4208	4209	4210	4211	4212	4214	4215	4216	4217	4219	4220	4221	4322	4323	4324	4325	4104
AZ	36	24	24	13	33	34	25	7	5	6	3	8	20	4	0	30	26	30	0	0	0	0	0
PH	0	10	0	16	16	2	2	4	30	32	0	0	0	0	0	0	0	0	0	0	0	0	0
CGS	16	20	23	18	2	17	22	39	18	27	53	51	38	15	17	30	43	43	16	9	2	2	1
SRV	2	10	11	6	6	1	4	2	6	12	11	16	10	4	0	4	4	0	2	6	9	4	0

Fig. 12: Handlers preference at London Heathrow airport Terminal 4

The results are summarised in tables which only show the robustness approaches which, at least in one instance of the disruptions for a given standard deviation, provide statistically significantly less collisions than other approaches evaluated, and cannot be said to be statistically worse than any of the approaches considered. The tables show for each standard deviation the number of times an approach cannot be said to be statistically significantly worse than any of the other approaches. The last column provides the sum of each result for each of the standard deviations. The case where all instances in a given standard deviation cannot be said to be statistically worse than any other are shown in bold text, and in underlined text for those cases which provide the highest number of all the approaches considered.

The results for the different robustness approaches, when applied to the data sets in Table 2 (data sets from HAL for London Heathrow airport Terminal 4) are summarised in Table 4. There is no apparent statistical difference between them for short disruptions (10 min standard deviation). For longer disruptions it is the UESRS with exponential unsupervised estimation function with $\beta = 0.03$, weight of 0.3125, with and without TRS approach which performs best for each of the similar disruptions considered. These results correspond to data sets where there is a sufficient number of gates for assignment to all of the activities ($N < \text{UMAP}_p$). No general gain is shown by combining the base approach with TRS. Nevertheless, there seems to be no detriment in combining with TRS either. The approaches ARS and BSARS do not perform well in any instance when either used alone or combined with TRS, which has also been observed when the rate of activities per gate increases (Table 6). These results also corroborate those presented in Lim and Wang (2005), namely, when the number of gates is greater than the UMAP, the exponential unsupervised estimation function performs better, but only when compared with the other unsupervised estimation functions.

Table 6 shows the summary results for the new data sets with an extra 37 groups for the same number of gates (a summary of data sets is shown in Table 5). These data sets are equivalent to a reduction in the number of gates available per group, representing more activities for the same number of resources. The UESRS approaches alone or in combination with TRS still perform well for low disruptions (particularly with the exponential estimation function with $\beta = 0.05$), and is even better than the PCBG(x), but PCBG(x) subsequently performed better for longer disruptions. The ARS and BSARS also achieved solutions with statistically significantly less collision when they were used together with the TRS than when used alone, but not when compared to UESRS and PCBG(x).

Table 4: Summary of statistical significance of AGAP robustness (significance level 0.05) using perturbed schedules generated from normal distributions of 10, 20 and 30 min standard deviations (x), SSEA1 for data sets H4T1009dd.

Approach	Standard Deviation (x) in min			Total
	10	20	30	
0.225PCBG(x)+0.00025TRS(2)	7	1	1	9
0.3125PCBG(x)+0.00025TRS(2)	7	1	4	12
0.225PCBG(x)	7	0	2	9
0.3125PCBG(x)	7	1	4	12
0.225UESRS(E0.03)+0.00025TRS(2)	7	4	5	16
0.225UESRS(E0.05)+0.00025TRS(2)	7	1	0	8
0.225UESRS(I4)+0.00025TRS(2)	7	1	0	8
0.225UESRS(I6)+0.00025TRS(2)	7	3	0	10
0.3125UESRS(E0.03)+0.00025TRS(2)	7	6	6	19
0.3125UESRS(E0.05)+0.00025TRS(2)	7	2	2	11
0.3125UESRS(I4)+0.00025TRS(2)	7	3	1	11
0.3125UESRS(I6)+0.00025TRS(2)	7	2	1	10
0.225UESRS(E0.03)	7	5	6	15
0.225UESRS(E0.05)	7	3	1	11
0.225UESRS(I4)	7	1	0	8
0.225UESRS(I6)	7	3	0	10
0.225UESRS(I15)	7	3	3	12
0.3125UESRS(E0.03)	7	6	6	19
0.3125UESRS(I4)	7	1	0	8
0.3125UESRS(I6)	7	3	2	12
0.3125UESRS(I15)	7	6	5	18

Table 5: Generated data sets information with an extra 37 groups.

ID	Date	LMAP	UMAP	LMAPp	UMAPp	No. Activ-ities	No. Parking Activi-ties
N4T100906	6 Sept 2010	17	20	23	26	164	21
N4T100907	7 Sept 2010	21	23	25	28	160	19
N4T100908	8 Sept 2010	18	20	23	25	169	24
N4T100909	9 Sept 2010	21	21	28	28	168	22
N4T100910	10 Sept 2010	19	20	20	21	164	21
N4T100911	11 Sept 2010	19	21	21	21	154	15
N4T100912	12 Sept 2010	19	21	23	24	167	22

The empirical results show, when comparing the results of Tables 3 and 4, that combining the approaches with TRS helps to reduce the number of collisions where there is a lower number of gates per activity. These results suggest that when fewer resources (gates) are available the increase in the influence of the buffer time is advantageous, given that there is more chance of future disruptions as there is less 'idle time' available for the overall problem. It is therefore anticipated that combining both UESRS and PCBG(x) with other approaches using the buffer time, such as ARS and BSARS, should also further improve the results. The ARS and BSARS are tailored to take account of the influence of the flights distribution over time, so increasing the penalty in periods where there is a higher demand for gates, which the experiments indicate improved results.

a) Robustness

The summary of the statistical significance of the different robustness approaches is shown in Tables 7 and 8, where the PCBG uses the same standard deviation as the normal distribution which was used to generate the perturbed schedules. The LMAP, UMAP, LMAP$_p$ and UMAP$_p$ from Table 2 are shown between brackets in the table heading for convenience as (LMAP, UMAP, LMAP$_p$, UMAP$_p$). The table only presents those approaches which either alone or combined with others

provide solutions with statistically significantly fewer collisions than other approaches studied and cannot be said to have more collisions than any of the other operators studied when used alone or in combination, which are shown with a tick. Only those approaches having at least one tick are shown.

Table 6: Summary of statistical significance of AGAP robustness (significance level = 0.05) using perturbed schedules generated from normal distributions of 10, 20 and 30 min standard deviations (x), SSEA1 for new data sets N4T1009dd with 37 extra groups each.

Approach	Standard Deviation (x) in min			Total
	10	20	30	
0.225PCBG(x)+0.00025TRS(2)	3	3	5	11
0.3125PCBG(x)+0.00025TRS(2)	2	6	6	14
0.225PCBG(x)	2	4	6	12
0.3125PCBG(x)	3	5	5	13
0.225UESRS(E0.03)+0.00025TRS(2)	5	0	0	5
0.225UESRS(E0.05)+0.00025TRS(2)	6	1	0	7
0.225UESRS(I4)+0.00025TRS(2)	3	0	0	3
0.225UESRS(I6)+0.00025TRS(2)	5	0	5	5
0.3125UESRS(E0.03)+0.00025TRS(2)	6	2	1	9
0.3125UESRS(E0.05)+0.00025TRS(2)	6	4	2	12
0.3125UESRS(I4)+0.00025TRS(2)	5	0	0	5
0.3125UESRS(I6)+0.00025TRS(2)	4	1	0	5
0.225UESRS(E0.03)	3	0	0	3
0.225UESRS(E0.05)	4	1	0	5
0.225UESRS(I4)	4	0	0	4
0.225UESRS(I6)	3	0	0	3
0.225UESRS(I15)	4	1	0	5
0.3125UESRS(E0.03)	5	2	0	7
0.3125UESRS(I4)	5	0	0	5
0.3125UESRS(I6)	4	1	0	5
0.3125UESRS(I15)	3	1	0	4

To speed up execution of the PCBG robustness approach instead of using the density function for the distribution (folded normal distribution), a pre-generated table of the accumulative probabilities was used for up to four times the standard deviation.

It should be noted that given that the PCBG used considers standard deviations equal to those used to build the perturbed data sets it may be considered biased and be expected to perform better. However the results obtained for data sets with a sufficient number of gates to assign all the activities shows that the UESRS performs better for different unsupervised functions than PCBG for all the disruption standard deviations considered.

V. Conclusions

Different algorithms and their parameters were studied to find characteristics which could be used to identify the algorithm and parameters most appropriate to the AGAP. Both the model and algorithms are derived by modifying those presented in previous work, and are based on the specific characteristics of the problem.

The time an aircraft expends parked at a gate has a considerable effect on the operations which take place up stream in the overall airport operation, especially when some of the resources required, such as gates, are limited. Delays in starting the departure sequencing may have important effects on the departure itself, which in turn may also require other aircraft to extend the time during which they are held at the gates. This could well affect other flights arriving which have had the same gates assigned to them. It would be therefore advisable to account for the effect of potential disturbances in the assignment plan and so some approaches were considered. The number of conflicts in perturbed schedules were used as a means of comparing the performance of different approaches. Different conditions were considered from when there are too few gates to assign to all flights, represented by LMAPp, when there are sufficient gates to service all the flight but at the expenses of a reduction on buffer time, represented by UMAPp, and when there are sufficient gates to assign all flight to the available gates without having to reduce the buffer time. It was concluded that

the empirical results indicate that the PCBG did not provide such good results as the UESRS regarding those conflicts where there are plentiful gates to which to assign activities. PCBG performance improved as the number of gates available to service the activities is reduced. Furthermore, it was noted that the close relationship between the PCBG approach and the perturbed base schedule used to calculate the conflicts, and which provides some bias in favour of the PCBG, may be reduced or removed if the buffer times, considered for the other robustness approaches, are modified accordingly. The combination of UESRS and PCBG with TRS provides good solutions, and there is still some potential for combining UESRS and PCBG with other approaches, such as ARS and BSARS, which take account of other problem characteristics which both UESRS and PCBG do not, so potentially further improving the robustness of the solutions reached.

Table 7: Summary AGAP robustness statistical significance (significance level 0.05) using perturbed schedules generated from normal distributions of 10, 20 and 30 min standard deviations and SSEA1.

Approach	H4T100906 (8, 10, 17, 19)			H4T100907 (11, 14, 18, 20)			H4T100908 (7, 10, 16, 18)			H4T100909 (8, 10, 18, 20)			H4T100910 (9, 12, 15, 18)			H4T100911 (9. 10, 16, 16)			H4T100912 (11, 11, 18, 19)		
	Standard Deviation (x) in min																				
	10	20	30	10	20	30	10	20	30	10	20	30	10	20	30	10	20	30	10	20	30
0.225PCBG(x)+0.00025TRS(2)	√	√		√			√			√			√			√			√		√
0.3125PCBG(x)+0.00025TRS(2)	√	√	√	√		√	√			√		√	√			√			√		√
0.225PCBG(x)	√			√			√			√		√	√			√			√		√
0.3125PCBG(x)	√	√	√	√		√	√			√		√	√		√	√			√		
0.225UESRS(E0.03)+0.00025TRS(2)	√	√	√	√			√		√	√	√		√	√	√	√		√	√	√	√
0.225UESRS(E0.05)+0.00025TRS(2)	√	√		√			√			√			√			√			√		
0.225UESRS(I4)+0.00025TRS(2)	√	√		√			√			√			√			√			√		
0.225UESRS(I6)+0.00025TRS(2)	√	√		√			√			√	√		√			√			√	√	
0.3125UESRS(E0.03)+0.00025TRS(2)	√	√		√	√	√	√	√	√	√		√	√	√	√	√	√	√	√	√	√
0.3125UESRS(E0.05)+0.00025TRS(2)	√	√	√	√			√			√			√			√			√	√	√
0.3125UESRS(I4)+0.00025TRS(2)	√	√		√			√			√			√			√	√		√	√	√
0.3125UESRS(I6)+0.00025TRS(2)	√	√		√			√			√			√			√			√	√	√
0.225UESRS(E0.03)	√	√	√	√			√	√	√	√	√		√	√		√			√	√	√
0.225UESRS(E0.05)	√	√		√			√			√	√		√			√			√	√	√
0.225UESRS(I4)	√	√		√			√			√			√			√			√		
0.225UESRS(I6)	√	√		√			√			√	√		√			√			√	√	
0.225UESRS(I15)	√	√					√			√	√	√	√			√		√	√	√	√
0.3125UESRS(E0.03)	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√			√	√	√
0.3125UESRS(I4)	√	√		√			√			√			√			√			√		
0.3125UESRS(I6)	√	√	√	√			√			√			√	√		√			√	√	√
0.3125UESRS(I15)	√	√		√	√	√	√	√	√	√	√	√	√			√	√	√	√	√	√

Table 8: Summary AGAP robustness statistical significance (significance level = 0.05) using perturbed schedules generated from normal distributions of 10, 20 and 30 min standard deviations and SSEA1 for new data sets with 37 extra groups each.

SSEA1 and population size 5 Approach	H4T100906 (17, 20, 23, 26)			H4T100907 (21, 23, 25, 28)			H4T100908 (18, 20, 23, 25)			H4T100909 (21. 21, 28, 28)			H4T100910 (19, 20, 20, 21)			H4T100911 (19. 21, 21, 21)			H4T100912 (19, 21, 23. 24)		
	Standard Deviation (x) in min																				
	10	20	30	10	20	30	10	20	30	10	20	30	10	20	30	10	20	30	10	20	30
0.225PCBG(x)+0.00025TRS(2)			√	√	√	√			√	√	√	√		√	√					√	
0.3125PCBG(x)+0.00025TRS(2)		√		√	√	√		√	√	√	√	√		√	√			√		√	√
0.225PCBG(x)			√	√	√	√			√	√	√	√		√				√		√	√
0.3125PCBG(x)		√	√	√				√	√	√				√	√		√	√	√	√	√
0.225UESRS(E0.03)+0.00025TRS(2)				√			√						√			√			√		
0.225UESRS(E0.05)+0.00025TRS(2)	√			√			√						√			√			√	√	
0.225UESRS(I4)+0.00025TRS(2)	√						√												√		
0.225UESRS(I6)+0.00025TRS(2)	√						√						√			√			√		
0.3125UESRS(E0.03)+0.00025TRS(2)				√			√		√	√			√			√	√		√	√	
0.3125UESRS(E0.05)+0.00025TRS(2)		√		√	√	√	√			√		√	√			√	√		√	√	
0.3125UESRS(I4)+0.00025TRS(2)	√						√						√			√			√		
0.3125UESRS(I6)+0.00025TRS(2)	√						√						√			√	√				
0.225UESRS(E0.03)				√			√						√								
0.225UESRS(E0.05)							√						√			√	√		√		
0.225UESRS(I4)	√						√						√						√		
0.225UESRS(I6)							√						√						√		
0.225UESRS(I15)							√						√			√	√		√		
0.3125UESRS(E0.03)	√						√						√			√	√		√	√	
0.3125UESRS(I4)	√						√						√			√			√		
0.3125UESRS(I6)							√						√			√	√		√		
0.3125UESRS(I15)							√						√			√	√				

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Nature Plus Plus Inspired Computing - The Superset of Nature Inspired Computing

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Abstract- The term "Nature Plus Plus Inspired Computing" is coined by us in this article. The abbreviation for this new term is "N++IC." Just like the C++ programming language is a superset of C programming language, Nature Plus Plus Inspired Computing (N++IC) field is a superset of the Nature Inspired Computing (NIC) field. We defined and introduced "Nature Plus Plus Inspired Computing Field" in this work. Several interesting opportunities in N++IC Field are shown for Artificial Intelligence Field Scientists and Students. We show a literature review of the N++IC Field after showing the definition of Nature Inspired Computing (NIC) Field. The primary purpose of publishing this innovative article is to show a new path to NIC Field Scientists so that they can come up with various innovative algorithms from scratch. As the focus of this article is to introduce N++IC to researchers across the globe, we added N++IC Field concepts to the Particle Swarm Optimization algorithm and created the "Children Cycle Riding Algorithm (CCR Algorithm)." Finally, results obtained by CCR Algorithm are shown, followed by Conclusions.

Keywords: nature inspired computing, nature plus plus inspired computing, artificial intelligence, children, evolutionary computing, computational intelligence, new area, interesting opportunities, children cycle riding, children swarm.

GJCST-C Classification: I.2.m

Strictly as per the compliance and regulations of:

Nature Plus Plus Inspired Computing - The Superset of Nature Inspired Computing

Satish Gajawada[α] & Hassan M. H. Mustafa[σ]

Abstract- The term "Nature Plus Plus Inspired Computing" is coined by us in this article. The abbreviation for this new term is "N++IC." Just like the C++ programming language is a superset of C programming language, Nature Plus Plus Inspired Computing (N++IC) field is a superset of the Nature Inspired Computing (NIC) field. We defined and introduced "Nature Plus Plus Inspired Computing Field" in this work. Several interesting opportunities in N++IC Field are shown for Artificial Intelligence Field Scientists and Students. We show a literature review of the N++IC Field after showing the definition of Nature Inspired Computing (NIC) Field. The primary purpose of publishing this innovative article is to show a new path to NIC Field Scientists so that they can come up with various innovative algorithms from scratch. As the focus of this article is to introduce N++IC to researchers across the globe, we added N++IC Field concepts to the Particle Swarm Optimization algorithm and created the "Children Cycle Riding Algorithm (CCR Algorithm)." Finally, results obtained by CCR Algorithm are shown, followed by Conclusions.

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Contribution of Authors:

1. Direct Contribution: Hassan M. H. Mustafa and Satish Gajawada made a direct and complete contribution to this article. They have contributed equally to this article.

I. Definition of New Nature Plus Plus Inspired Computing Field

Nature Inspired Computing (NIC) Algorithms take inspiration from Mother Nature. Nature Inspired Computing Algorithms are a subset of Nature Plus Plus Inspired Computing (N++IC) Field Algorithms. Hence an algorithm belonging to the NIC field also belongs to the N++IC field. If an algorithm takes inspiration from Artificial things in addition to inspiration taken from nature, then such algorithms belong to both NIC and N++IC fields. Also, there can be algorithms that can take inspiration completely from Artificial things, and there is no inspiration taken from nature, then such algorithms belong only to the N++IC field and not the NIC field. There are three types of algorithms. Algorithms that take inspiration from nature only. The second type of algorithms are such that they take inspiration only from artificial things. The third type of algorithms takes inspiration from both nature as well as artificial things. The first category of algorithms belongs to NIC. The second category of algorithms belongs only to the N++IC field and not the NIC field. The third category of algorithms belongs to both NIC and N++IC fields. All three types of algorithms belong to the N++IC field. In the N++IC field, we added one more type of algorithms in addition to NIC field algorithms. Hence NIC field is a subset of the N++IC field.

II. Interesting Opportunities in Nature Plus Plus Inspired Computing Field

There are INTERESTING OPPORTUNITIES for NATURE INSPIRED COMPUTING (NIC) field Research Scientists in NATURE PLUS PLUS INSPIRED COMPUTING (N++IC) field. Some of them are shown below:

1. B.Tech Project in N++IC field, IIT Roorkee
2. M.Tech Project in N++IC field, Harvard University
3. Ph.D. in N++IC field, IIT Hyderabad
4. Postdoc in N++IC field, Stanford University
5. International Association of N++IC field, Singapore
6. International Conference on N++IC field, Dubai
7. Transactions on NIC and N++IC, United Kingdom
8. International Journal on N++IC field, Australia
9. International Workshop on N++IC field, Hong Kong
10. The foundation on N++IC, New York
11. Seminar on N++IC field at Technical Festival in Pakistan colleges
12. Microsoft R&D team on N++IC field
13. IBM R&D N++IC field Research Labs, IBM Hyderabad
14. YouTube videos on N++IC and NIC fields by Google R&D team, Google Delhi
15. Springer Journal on N++IC
16. Elsevier book on N++IC
17. IEEE N++IC Society, Japan
18. To become a Scientist in the N++IC field
19. A Course on N++IC by Coursera

Author α: Independent Inventor and Scientist. Alumnus, Indian Institute of Technology Roorkee. The Creator of Artificial Satisfaction Field. Founder and Father of Artificial Human Optimization Field. Inventor of Deep Loving Field. Designer of Nature Plus Plus Inspired Computing Field. Inventor of Artificial Soul Optimization and Artificial God Optimization Fields. e-mail: satish.gajawada.iit@gmail.com
Author σ: Banha University, Egypt.

20. Advanced N++IC - A New subject
21. IBMSUR Award for a Professor in N++IC FIELD at IIT Hyderabad

III. Nature Inspired Computing

According to [1], the definition of NATURE INSPIRED COMPUTING is shown below in double-quotes as it is:

"The field of nature-inspired computing (NIC) is interdisciplinary in nature combining computing science with knowledge from different branches of sciences, e.g. physics, chemistry, biology, mathematics and engineering, that allows development of new computational tools such as algorithms, hardware, or wetware for problem-solving, synthesis of patterns, behaviours and organisms."

IV. Literature Review

There are many Research Scientists and Students who are working in the field of Nature Inspired Computing. You will easily find thousands of references for Nature Inspired Computing when you search on Google. In this paper, our focus is to define a new field titled Nature Plus Plus Inspired Computing (N++IC) and how it is related to Nature Inspired Computing (NIC). Hence for the sake of completeness, we just show [1] - [10] articles that come under NIC. As defined, NIC is a subset of N++IC, and hence all [1] - [10] articles also belong to the N++IC field.

V. Children Cycle Riding Algorithm

Figure 1 shows the Children Cycle Riding Algorithm (CCRA). In this section, we explain CCRA. In the beginning, the iteration counter is set to zero, and all Artificial Children are initialized. The search space is full of Artificial sharp stones, which may result in damaging the tyre of the Artificial Child's Cycle. Hence we have Cycle Tyre Damage Probability. After the damage of the cycle tyre, the child repairs his cycle tyre with probability Cycle Tyre Repaired Probability.

If a cycle tyre is damaged, then there are two possibilities. Either Artificial Child repairs his cycle tyre or not. If the cycle tyre is damaged and Artificial Child gets his cycle repaired, then Artificial Child can move in search space and hence updates Velocity and Position. If the cycle tyre is damaged and Artificial Child cannot repair his cycle tyre then Artificial Child is halted and does not update his Velocity and Position. On the other hand, if Artificial Child's Cycle tyre is not damaged, then he can move in search space and hence updates Velocity and Position. At the end of the iteration, the iteration counter is incremented. Now the control goes to line number 2. This process is continued until the termination condition is reached. Figure 1 is shown below:

```
1) All Artificial Children are initialized, and the iteration counter is set to zero.
2) Artificial Children identifies their local best
3) Artificial Children identifies their global best
4) Artificial Children identifies their local worst
5) Artificial Children identifies their global worst
6) for each Artificial Child do
7)       if ( random(0,1) < CycleTyreDamageProbability) then
8)                if ( random(0,1) < CycleTyreRepairedProbability) then
9)                        Artificial Child updates Velocity
10)                       Artificial Child updates Position
11)               else
12)                       // If Cycle tyre is damaged and it is not repaired then Artificial Child is
                          // halted and does nothing
13)               end if
14)       else
15)               Artificial Child updates Velocity
16)               Artificial Child updates Position
17)       end if
18) end for
19) Update Iteration Counter
20) if (termination_condition_reached is not true) then
21)       jump to line number 2
22) end if
```

Figure 1: Children Cycle Riding Algorithm (CCRA)

VI. Results

The Human Poverty Particle Swarm Optimization (HPPSO) proposed in [11], and Children Cycle Riding Algorithm (CCRA) proposed in this article are MATHEMATICALLY EQUAL. In [11], it was shown that both HPPSO and PSO performed well on all benchmark functions. Hence due to Mathematical EQUALITY, both CCRA and PSO Algorithms performed well on all benchmark functions.

VII. Conclusions

"Nature Plus Plus Inspired Computing (N++IC)" field is designed and introduced in this work. The difference between the two fields NIC and the N++IC is clearly explained. Children Cycle Riding Algorithm (CCRA) is designed, and results show that CCRA performed as good as the Particle Swarm Optimization algorithm. Some interesting opportunities in the N++IC field are shown for NIC field Students and Research Scientists. Research Scientists and Students did a lot of research in the NIC field. There is a lot of scope in the direction where Algorithms are inspired by both nature and Artificial things. Also, there exists a lot of scope in the direction where Algorithms are inspired by Artificial things only. Children are natural, and cycle riding is Artificial. Hence CCRA is designed by taking inspiration from both nature and Artificial things. This paper is mainly published to introduce N++IC Field to the world. Hence we just added N++IC concepts to the Particle Swarm Optimization algorithm and created CCRA. As the new field is proposed in this article, the next step for Researchers is to create new N++IC field Algorithms from scratch.

Acknowledgments

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Tips for writing a good quality Computer Science Research Paper

Techniques for writing a good quality computer science research paper:

1. Choosing the topic: In most cases, the topic is selected by the interests of the author, but it can also be suggested by the guides. You can have several topics, and then judge which you are most comfortable with. This may be done by asking several questions of yourself, like "Will I be able to carry out a search in this area? Will I find all necessary resources to accomplish the search? Will I be able to find all information in this field area?" If the answer to this type of question is "yes," then you ought to choose that topic. In most cases, you may have to conduct surveys and visit several places. Also, you might have to do a lot of work to find all the rises and falls of the various data on that subject. Sometimes, detailed information plays a vital role, instead of short information. Evaluators are human: The first thing to remember is that evaluators are also human beings. They are not only meant for rejecting a paper. They are here to evaluate your paper. So present your best aspect.

2. Think like evaluators: If you are in confusion or getting demotivated because your paper may not be accepted by the evaluators, then think, and try to evaluate your paper like an evaluator. Try to understand what an evaluator wants in your research paper, and you will automatically have your answer. Make blueprints of paper: The outline is the plan or framework that will help you to arrange your thoughts. It will make your paper logical. But remember that all points of your outline must be related to the topic you have chosen.

3. Ask your guides: If you are having any difficulty with your research, then do not hesitate to share your difficulty with your guide (if you have one). They will surely help you out and resolve your doubts. If you can't clarify what exactly you require for your work, then ask your supervisor to help you with an alternative. He or she might also provide you with a list of essential readings.

4. Use of computer is recommended: As you are doing research in the field of computer science then this point is quite obvious. Use right software: Always use good quality software packages. If you are not capable of judging good software, then you can lose the quality of your paper unknowingly. There are various programs available to help you which you can get through the internet.

5. Use the internet for help: An excellent start for your paper is using Google. It is a wondrous search engine, where you can have your doubts resolved. You may also read some answers for the frequent question of how to write your research paper or find a model research paper. You can download books from the internet. If you have all the required books, place importance on reading, selecting, and analyzing the specified information. Then sketch out your research paper. Use big pictures: You may use encyclopedias like Wikipedia to get pictures with the best resolution. At Global Journals, you should strictly follow here.

6. Bookmarks are useful: When you read any book or magazine, you generally use bookmarks, right? It is a good habit which helps to not lose your continuity. You should always use bookmarks while searching on the internet also, which will make your search easier.

7. Revise what you wrote: When you write anything, always read it, summarize it, and then finalize it.

8. Make every effort: Make every effort to mention what you are going to write in your paper. That means always have a good start. Try to mention everything in the introduction—what is the need for a particular research paper. Polish your work with good writing skills and always give an evaluator what he wants. Make backups: When you are going to do any important thing like making a research paper, you should always have backup copies of it either on your computer or on paper. This protects you from losing any portion of your important data.

9. Produce good diagrams of your own: Always try to include good charts or diagrams in your paper to improve quality. Using several unnecessary diagrams will degrade the quality of your paper by creating a hodgepodge. So always try to include diagrams which were made by you to improve the readability of your paper. Use of direct quotes: When you do research relevant to literature, history, or current affairs, then use of quotes becomes essential, but if the study is relevant to science, use of quotes is not preferable.

10.Use proper verb tense: Use proper verb tenses in your paper. Use past tense to present those events that have happened. Use present tense to indicate events that are going on. Use future tense to indicate events that will happen in the future. Use of wrong tenses will confuse the evaluator. Avoid sentences that are incomplete.

11. Pick a good study spot: Always try to pick a spot for your research which is quiet. Not every spot is good for studying.

12. Know what you know: Always try to know what you know by making objectives, otherwise you will be confused and unable to achieve your target.

13. Use good grammar: Always use good grammar and words that will have a positive impact on the evaluator; use of good vocabulary does not mean using tough words which the evaluator has to find in a dictionary. Do not fragment sentences. Eliminate one-word sentences. Do not ever use a big word when a smaller one would suffice.

Verbs have to be in agreement with their subjects. In a research paper, do not start sentences with conjunctions or finish them with prepositions. When writing formally, it is advisable to never split an infinitive because someone will (wrongly) complain. Avoid clichés like a disease. Always shun irritating alliteration. Use language which is simple and straightforward. Put together a neat summary.

14. Arrangement of information: Each section of the main body should start with an opening sentence, and there should be a changeover at the end of the section. Give only valid and powerful arguments for your topic. You may also maintain your arguments with records.

15. Never start at the last minute: Always allow enough time for research work. Leaving everything to the last minute will degrade your paper and spoil your work.

16. Multitasking in research is not good: Doing several things at the same time is a bad habit in the case of research activity. Research is an area where everything has a particular time slot. Divide your research work into parts, and do a particular part in a particular time slot.

17. Never copy others' work: Never copy others' work and give it your name because if the evaluator has seen it anywhere, you will be in trouble. Take proper rest and food: No matter how many hours you spend on your research activity, if you are not taking care of your health, then all your efforts will have been in vain. For quality research, take proper rest and food.

18. Go to seminars: Attend seminars if the topic is relevant to your research area. Utilize all your resources.

19. Refresh your mind after intervals: Try to give your mind a rest by listening to soft music or sleeping in intervals. This will also improve your memory. Acquire colleagues: Always try to acquire colleagues. No matter how sharp you are, if you acquire colleagues, they can give you ideas which will be helpful to your research.

20. Think technically: Always think technically. If anything happens, search for its reasons, benefits, and demerits. Think and then print: When you go to print your paper, check that tables are not split, headings are not detached from their descriptions, and page sequence is maintained.

21. Adding unnecessary information: Do not add unnecessary information like "I have used MS Excel to draw graphs." Irrelevant and inappropriate material is superfluous. Foreign terminology and phrases are not apropos. One should never take a broad view. Analogy is like feathers on a snake. Use words properly, regardless of how others use them. Remove quotations. Puns are for kids, not grunt readers. Never oversimplify: When adding material to your research paper, never go for oversimplification; this will definitely irritate the evaluator. Be specific. Never use rhythmic redundancies. Contractions shouldn't be used in a research paper. Comparisons are as terrible as clichés. Give up ampersands, abbreviations, and so on. Remove commas that are not necessary. Parenthetical words should be between brackets or commas. Understatement is always the best way to put forward earth-shaking thoughts. Give a detailed literary review.

22. Report concluded results: Use concluded results. From raw data, filter the results, and then conclude your studies based on measurements and observations taken. An appropriate number of decimal places should be used. Parenthetical remarks are prohibited here. Proofread carefully at the final stage. At the end, give an outline to your arguments. Spot perspectives of further study of the subject. Justify your conclusion at the bottom sufficiently, which will probably include examples.

23. Upon conclusion: Once you have concluded your research, the next most important step is to present your findings. Presentation is extremely important as it is the definite medium though which your research is going to be in print for the rest of the crowd. Care should be taken to categorize your thoughts well and present them in a logical and neat manner. A good quality research paper format is essential because it serves to highlight your research paper and bring to light all necessary aspects of your research.

Informal Guidelines of Research Paper Writing

Key points to remember:

- Submit all work in its final form.
- Write your paper in the form which is presented in the guidelines using the template.
- Please note the criteria peer reviewers will use for grading the final paper.

Final points:

One purpose of organizing a research paper is to let people interpret your efforts selectively. The journal requires the following sections, submitted in the order listed, with each section starting on a new page:

The introduction: This will be compiled from reference matter and reflect the design processes or outline of basis that directed you to make a study. As you carry out the process of study, the method and process section will be constructed like that. The results segment will show related statistics in nearly sequential order and direct reviewers to similar intellectual paths throughout the data that you gathered to carry out your study.

The discussion section:

This will provide understanding of the data and projections as to the implications of the results. The use of good quality references throughout the paper will give the effort trustworthiness by representing an alertness to prior workings.

Writing a research paper is not an easy job, no matter how trouble-free the actual research or concept. Practice, excellent preparation, and controlled record-keeping are the only means to make straightforward progression.

General style:

Specific editorial column necessities for compliance of a manuscript will always take over from directions in these general guidelines.

To make a paper clear: Adhere to recommended page limits.

Mistakes to avoid:

- Insertion of a title at the foot of a page with subsequent text on the next page.
- Separating a table, chart, or figure—confine each to a single page.
- Submitting a manuscript with pages out of sequence.
- In every section of your document, use standard writing style, including articles ("a" and "the").
- Keep paying attention to the topic of the paper.
- Use paragraphs to split each significant point (excluding the abstract).
- Align the primary line of each section.
- Present your points in sound order.
- Use present tense to report well-accepted matters.
- Use past tense to describe specific results.
- Do not use familiar wording; don't address the reviewer directly. Don't use slang or superlatives.
- Avoid use of extra pictures—include only those figures essential to presenting results.

Title page:

Choose a revealing title. It should be short and include the name(s) and address(es) of all authors. It should not have acronyms or abbreviations or exceed two printed lines.

Abstract: This summary should be two hundred words or less. It should clearly and briefly explain the key findings reported in the manuscript and must have precise statistics. It should not have acronyms or abbreviations. It should be logical in itself. Do not cite references at this point.

An abstract is a brief, distinct paragraph summary of finished work or work in development. In a minute or less, a reviewer can be taught the foundation behind the study, common approaches to the problem, relevant results, and significant conclusions or new questions.

Write your summary when your paper is completed because how can you write the summary of anything which is not yet written? Wealth of terminology is very essential in abstract. Use comprehensive sentences, and do not sacrifice readability for brevity; you can maintain it succinctly by phrasing sentences so that they provide more than a lone rationale. The author can at this moment go straight to shortening the outcome. Sum up the study with the subsequent elements in any summary. Try to limit the initial two items to no more than one line each.

Reason for writing the article—theory, overall issue, purpose.

- Fundamental goal.
- To-the-point depiction of the research.
- Consequences, including definite statistics—if the consequences are quantitative in nature, account for this; results of any numerical analysis should be reported. Significant conclusions or questions that emerge from the research.

Approach:

- Single section and succinct.
- An outline of the job done is always written in past tense.
- Concentrate on shortening results—limit background information to a verdict or two.
- Exact spelling, clarity of sentences and phrases, and appropriate reporting of quantities (proper units, important statistics) are just as significant in an abstract as they are anywhere else.

Introduction:

The introduction should "introduce" the manuscript. The reviewer should be presented with sufficient background information to be capable of comprehending and calculating the purpose of your study without having to refer to other works. The basis for the study should be offered. Give the most important references, but avoid making a comprehensive appraisal of the topic. Describe the problem visibly. If the problem is not acknowledged in a logical, reasonable way, the reviewer will give no attention to your results. Speak in common terms about techniques used to explain the problem, if needed, but do not present any particulars about the protocols here.

The following approach can create a valuable beginning:

- Explain the value (significance) of the study.
- Defend the model—why did you employ this particular system or method? What is its compensation? Remark upon its appropriateness from an abstract point of view as well as pointing out sensible reasons for using it.
- Present a justification. State your particular theory(-ies) or aim(s), and describe the logic that led you to choose them.
- Briefly explain the study's tentative purpose and how it meets the declared objectives.

Approach:

Use past tense except for when referring to recognized facts. After all, the manuscript will be submitted after the entire job is done. Sort out your thoughts; manufacture one key point for every section. If you make the four points listed above, you will need at least four paragraphs. Present surrounding information only when it is necessary to support a situation. The reviewer does not desire to read everything you know about a topic. Shape the theory specifically—do not take a broad view.

As always, give awareness to spelling, simplicity, and correctness of sentences and phrases.

Procedures (methods and materials):

This part is supposed to be the easiest to carve if you have good skills. A soundly written procedures segment allows a capable scientist to replicate your results. Present precise information about your supplies. The suppliers and clarity of reagents can be helpful bits of information. Present methods in sequential order, but linked methodologies can be grouped as a segment. Be concise when relating the protocols. Attempt to give the least amount of information that would permit another capable scientist to replicate your outcome, but be cautious that vital information is integrated. The use of subheadings is suggested and ought to be synchronized with the results section.

When a technique is used that has been well-described in another section, mention the specific item describing the way, but draw the basic principle while stating the situation. The purpose is to show all particular resources and broad procedures so that another person may use some or all of the methods in one more study or referee the scientific value of your work. It is not to be a step-by-step report of the whole thing you did, nor is a methods section a set of orders.

Materials:

Materials may be reported in part of a section or else they may be recognized along with your measures.

Methods:

- Report the method and not the particulars of each process that engaged the same methodology.
- Describe the method entirely.
- To be succinct, present methods under headings dedicated to specific dealings or groups of measures.
- Simplify—detail how procedures were completed, not how they were performed on a particular day.
- If well-known procedures were used, account for the procedure by name, possibly with a reference, and that's all.

Approach:

It is embarrassing to use vigorous voice when documenting methods without using first person, which would focus the reviewer's interest on the researcher rather than the job. As a result, when writing up the methods, most authors use third person passive voice.

Use standard style in this and every other part of the paper—avoid familiar lists, and use full sentences.

What to keep away from:

- Resources and methods are not a set of information.
- Skip all descriptive information and surroundings—save it for the argument.
- Leave out information that is immaterial to a third party.

Results:

The principle of a results segment is to present and demonstrate your conclusion. Create this part as entirely objective details of the outcome, and save all understanding for the discussion.

The page length of this segment is set by the sum and types of data to be reported. Use statistics and tables, if suitable, to present consequences most efficiently.

You must clearly differentiate material which would usually be incorporated in a study editorial from any unprocessed data or additional appendix matter that would not be available. In fact, such matters should not be submitted at all except if requested by the instructor.

Content:

- Sum up your conclusions in text and demonstrate them, if suitable, with figures and tables.
- In the manuscript, explain each of your consequences, and point the reader to remarks that are most appropriate.
- Present a background, such as by describing the question that was addressed by creation of an exacting study.
- Explain results of control experiments and give remarks that are not accessible in a prescribed figure or table, if appropriate.
- Examine your data, then prepare the analyzed (transformed) data in the form of a figure (graph), table, or manuscript.

What to stay away from:

- Do not discuss or infer your outcome, report surrounding information, or try to explain anything.
- Do not include raw data or intermediate calculations in a research manuscript.
- Do not present similar data more than once.
- A manuscript should complement any figures or tables, not duplicate information.
- Never confuse figures with tables—there is a difference.

Approach:

As always, use past tense when you submit your results, and put the whole thing in a reasonable order.

Put figures and tables, appropriately numbered, in order at the end of the report.

If you desire, you may place your figures and tables properly within the text of your results section.

Figures and tables:

If you put figures and tables at the end of some details, make certain that they are visibly distinguished from any attached appendix materials, such as raw facts. Whatever the position, each table must be titled, numbered one after the other, and include a heading. All figures and tables must be divided from the text.

Discussion:

The discussion is expected to be the trickiest segment to write. A lot of papers submitted to the journal are discarded based on problems with the discussion. There is no rule for how long an argument should be.

Position your understanding of the outcome visibly to lead the reviewer through your conclusions, and then finish the paper with a summing up of the implications of the study. The purpose here is to offer an understanding of your results and support all of your conclusions, using facts from your research and generally accepted information, if suitable. The implication of results should be fully described.

Infer your data in the conversation in suitable depth. This means that when you clarify an observable fact, you must explain mechanisms that may account for the observation. If your results vary from your prospect, make clear why that may have happened. If your results agree, then explain the theory that the proof supported. It is never suitable to just state that the data approved the prospect, and let it drop at that. Make a decision as to whether each premise is supported or discarded or if you cannot make a conclusion with assurance. Do not just dismiss a study or part of a study as "uncertain."

Research papers are not acknowledged if the work is imperfect. Draw what conclusions you can based upon the results that you have, and take care of the study as a finished work.

- You may propose future guidelines, such as how an experiment might be personalized to accomplish a new idea.
- Give details of all of your remarks as much as possible, focusing on mechanisms.
- Make a decision as to whether the tentative design sufficiently addressed the theory and whether or not it was correctly restricted. Try to present substitute explanations if they are sensible alternatives.
- One piece of research will not counter an overall question, so maintain the large picture in mind. Where do you go next? The best studies unlock new avenues of study. What questions remain?
- Recommendations for detailed papers will offer supplementary suggestions.

Approach:

When you refer to information, differentiate data generated by your own studies from other available information. Present work done by specific persons (including you) in past tense.

Describe generally acknowledged facts and main beliefs in present tense.

The Administration Rules

Administration Rules to Be Strictly Followed before Submitting Your Research Paper to Global Journals Inc.

Please read the following rules and regulations carefully before submitting your research paper to Global Journals Inc. to avoid rejection.

Segment draft and final research paper: You have to strictly follow the template of a research paper, failing which your paper may get rejected. You are expected to write each part of the paper wholly on your own. The peer reviewers need to identify your own perspective of the concepts in your own terms. Please do not extract straight from any other source, and do not rephrase someone else's analysis. Do not allow anyone else to proofread your manuscript.

Written material: You may discuss this with your guides and key sources. Do not copy anyone else's paper, even if this is only imitation, otherwise it will be rejected on the grounds of plagiarism, which is illegal. Various methods to avoid plagiarism are strictly applied by us to every paper, and, if found guilty, you may be blacklisted, which could affect your career adversely. To guard yourself and others from possible illegal use, please do not permit anyone to use or even read your paper and file.

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Topics	Grades		
	A-B	**C-D**	**E-F**
Abstract	Clear and concise with appropriate content, Correct format. 200 words or below	Unclear summary and no specific data, Incorrect form Above 200 words	No specific data with ambiguous information Above 250 words
Introduction	Containing all background details with clear goal and appropriate details, flow specification, no grammar and spelling mistake, well organized sentence and paragraph, reference cited	Unclear and confusing data, appropriate format, grammar and spelling errors with unorganized matter	Out of place depth and content, hazy format
Methods and Procedures	Clear and to the point with well arranged paragraph, precision and accuracy of facts and figures, well organized subheads	Difficult to comprehend with embarrassed text, too much explanation but completed	Incorrect and unorganized structure with hazy meaning
Result	Well organized, Clear and specific, Correct units with precision, correct data, well structuring of paragraph, no grammar and spelling mistake	Complete and embarrassed text, difficult to comprehend	Irregular format with wrong facts and figures
Discussion	Well organized, meaningful specification, sound conclusion, logical and concise explanation, highly structured paragraph reference cited	Wordy, unclear conclusion, spurious	Conclusion is not cited, unorganized, difficult to comprehend
References	Complete and correct format, well organized	Beside the point, Incomplete	Wrong format and structuring

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