An Interactive Framework to Allocate and Manage Teaching Workload using Hybrid OLAP Cubes

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Abstract— **Assignment of teaching workload is an essential annual ritual in all academic institutions. Depending upon the structure and complexity, it can be a painful process for department heads and administrative deans who are responsible for resource allocation. We present a framework which uses business intelligence techniques to allow asynchronous data entry, analysis and reporting in a collaborative environment to assist with the decision-making process. To begin, the first-tier administrators make workload assignments in consultation with faculty using interactive web forms, data is pushed to the underlying database or cube, reports are rendered, and memos are auto-generated. Deans responsible for approval are able to review the information along several dimensions and make informed decisions regarding the assignments. Historical data remains available for future years for trends and analysis. Besides achieving the benefits from transparency of the process, the framework exploits both OLAP cubes and relational data stores for optimum performance.**

Keywords—business intelligence, online analytical processing, OLAP cubes, teaching workload management

I. INTRODUCTION

Despite existence of general guidelines, faculty supervisors face the daunting task of course assignments for the upcoming academic year(s). This exercise is different each year due to the changing curriculum, full-time vs part-time faculty, budgetary constraints, sabbaticals and rotational requirements. Further, these assignments must be consistent with collective agreements in terms of load, annual reviews, merit awards and a variety of other factors. The initial draft is generally prepared by department chairs in consultation with the faculty members. Unfortunately, this draft is prepared on non-standard spreadsheets without any structural constraints. The Deans are then faced with the daunting task of compiling/aggregating all information coming from different departments in several different formats. This can lead to miscalculated allocation of resources.

While spreadsheets continue to be a dominating mechanism for arranging data and producing static reports, Business Intelligence (BI) is now widely used in all data-centric areas such as finance, sales, marketing, law enforcement, social networks, and healthcare. The analytics layer of business intelligence involves building of multi-dimensional OLAP (Online Analytical Processing) cubes which allows aggregation, and slicing/dicing of data along multiple dimensions [1]. The reporting layer provides the ability to visually observe the Key Performance Indicators (KPIs) and navigate to finer granularity, where necessary. It should, however, be noted that in some cases the use of OLAP cubes can be an unnecessary overhead and direct accesses from the database can yield the desired reports [2]. The concept of hybrid OLAP (HOLAP) lies between these two extremes which exploits both single cubes and relational data stores [3].

In this paper, we present a framework which uses BI fundamentals together with web tools for informed decision-making in a collaborative environment. This framework consists of data entry web forms, an interactive dashboard, printable and exportable reports at various granularities, multi-dimensional OLAP cubes, a relational database and a web interface. In addition, the framework also allows auto-generation of contract memos to further reduce administrative overhead. A number of BI suites currently exist which provide a variety of capabilities ranging from integration to reporting [4]. We have chosen MS SQL Server 2016 as our platform because of its integrated BI tool stack as well as the ease of rendering reports via ASP.NET wrapper [5]. It should be emphasized here that the intent of this paper is not to redefine faculty workload, but the focus is on streamlining the process for assignment, analysis, reporting and approval using state of the art technologies.

The paper is organized as follows: we first summarize the limited related work; second, we describe the components of our proposed framework, followed by a sample of web forms and reports. Finally, we conclude the paper by summarizing the benefits of the framework and future direction.

II. RELATED WORK

In research-oriented institutions, teaching workload accounts for a fraction (say, 40%) of faculty member's load, the remaining being split towards research and service activities. Currently, there is no standardized way of assigning teaching workloads, even within the same institution. Educational institutions use various workload formulae for equitable assignment of teaching workloads and consider aspects such as teaching contact hours, (new) course preparation, teaching multiple sections, and mode of delivery [6]. Though some of these items are quantifiable, credit for informal workload is difficult to assess and responsible administrative personnel

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always struggle with approval of such requests. The use of business intelligence for educational management involving decision-making at top management and other levels has been widely emphasized [7] [8] [9]. However, the focus has mostly remained on academic outcomes, student experience, enrolments and retention. Some applications are geared towards administrative effectiveness and efficiency, but applications specific to workload management are difficult to find.

III. Proposed Framework

Our proposed framework provides an end-to-end solution which begins with entering of new data and ends with auto-generation of formal memos for the faculty outlining their workload in the upcoming year. In addition, trends and analysis are made available for perusal of the administrative bodies. The data is sliced along multiple dimensions and produces reports on historical, current and future plans. The structure of the institution is as follows: there are separate academic units each with its own Dean; each academic unit has several departments offering one or more programs; each department is managed by a Chair. There are approximately 400 full-time and part-time faculty members who are assigned to teach courses. Data entry is accomplished through web forms developed in ASP.NET making them accessible through a web interface. The data for courses and faculty is somewhat static in nature whereas the workload assignments are done on an annual basis with provision for revisions at any time. The data is captured in a backend database and pushed to a 7-dimensional cube (Figure 1) upon a single click. The design of this cube deviates from the traditional star and/or snowflake structure due to size and performance reasons. Once the cube is processed (usually, in less than ten seconds), the reports are rendered through an ASP.NET interface which provides filters to select academic years, sub-units, departments and programs. Access to these interfaces is authenticated through an Active Directory whereas access to individual components is controlled through an access control list embedded in the underlying database. Multiple users are allowed though only one can process the cube at any given time; simultaneous requests to process the cube are queued.

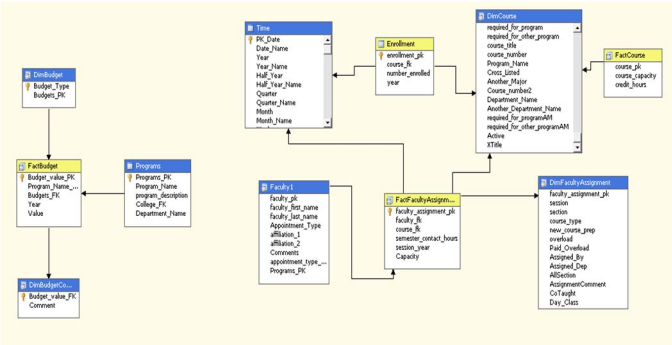


Figure 1. The Hybrid OLAP cube

The landing page consists of four main tabs for navigation to different areas of the framework: data entry, reporting, Dean's dashboard and Admin. Each of these tabs contain drop-down menus as described below.

A. Data Entry

Data entry is divided into five categories – courses, faculty, workload assignments, leaves and informal workload. Ideally, the first two should be extracted from institutional repositories, but this access was not available for the current research project. Besides the typical fields, the course profiles also specify whether a given course is cross-listed with other courses within or across departments. Similarly, a course may be required or elective in the home and other programs. The instructors can be designated as sessional, part-time, lecturer or tenured/tenure-track faculty. A faculty member can also have multiple affiliations if they hold appointments in more than one department.

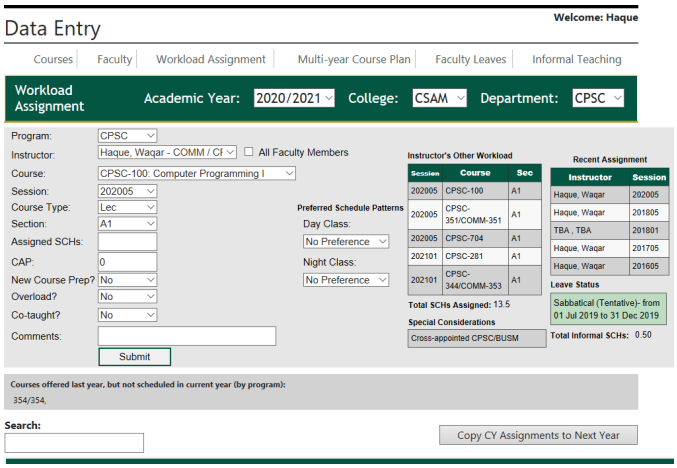


Figure 2. Workload assignment data entry

The workload assignment web form (Figure *2*) is the key data entry source which provides an interactive interface linked with a backend database. This interface does not only capture data, but also presents other information to assist with the new assignment. This includes current assignments of the faculty member, past instructors for the selected course, upcoming leaves, accrued informal workload, and special considerations, if any. By default, all dropdown lists (courses and faculty) only contain the elements associated with the department, thus making it impossible to assign a course which belongs to another department. This enforces access control by design. However, there is provision to assign a course to any instructor in the institution regardless of his/her affiliation. This provision is enabled through a check box. For the selected academic year, one of the four sessions can be selected, type of the course is specified (lecture, tutorial, seminar, lab, etc.) and the allocated hours are entered. In addition, it is also recorded whether the course being assigned is a new preparation for the instructor, and whether it constitutes overload teaching. In the latter case, it can be specified whether the overload is voluntary or on paid basis. In case, the course is being co-taught by more than one instructor, relevant information for the other instructor is also captured. Finally, any comments related to this specific assignment can be entered. The *Submit* button confirms successful entry of the record in the database. Alternatively, it highlights the fields which may have violated data integrity constraints, if any.

Search:

		Name	Course	Session	Type	Sec	SCH	CAP	New Course	OVLD	Paid	Co-taught	Comments
Add Lab(s)/Tut(s)	Edit Delete	Haque, Waqar	CPSC-100: Computer Programming I	202005	Lec	A1	3	60	No	No	No	No	TA support for labs
	Edit Delete	Haque, Waqar	CPSC-704: Graduate Seminar in Computer Science	202005	Sem	A1	1.5	10	No	No	No	No	May switch with 100 Tut
Add Lab(s)/Tut(s)	Edit Delete	Haque, Waqar	CPSC-281: Data Structures I	202101	Lec	A1	3	30	No	No	No	No	
Add Lab(s)/Tut(s)	Edit Delete	TBA , TBA	CPSC-324: Introduction to Database Systems	202101	Lec	A1	3	25	No	No	No	No	
	Edit Delete	TA1, TA1	CPSC-100: Computer Programming I	202005	Lab	L1	1.5	15	No	No	No	No	

Figure 3. Grid view (workload)

Faculty Workload Snapshot: CPSC
Academic year: 2020/21

Appointment Type	Instructor	202005		202101		Total SCHs		Cross-listed	Dist Crs	Crs Rel	New Prep	Overload		Teaching Levels	Instructor Comments
		Courses	SCH	Courses	SCH	Pgm	Other					V	P		
Tenure Track / AP	Haque, Waqar ⓘ	CPSC-100(A1), CPSC-499(A1)*, CPSC-704(A1), CPSC-706(A1)* CPSC-351/COMM-351(A1) ⓘ	9.0	CPSC-281(A1) CPSC-344/COMM-353(A1)	3.0	12.0	6.0	2	7	-	1	-	1	1xx 2xx 3xx 4xx 7xx	Cross-appointed CPSC/BUSM
	Total:		**9.0**		**3.0**	**12.0**									
P/T Instructor	TBA , TBA	CPSC-499(A1)*, CPSC-706(A1)* ⓘ	2.5	CPSC-324(A1)	3.0	5.5	-	-	3	-	1	-	1	3xx 4xx 7xx	
	Total:		**2.5**		**3.0**	**5.5**									
TA	TA1, TA1	CPSC-100(L1, L2, L3)	4.5			4.5	-	-	1						
	TA2, TA2	CPSC-100(T1, T2)	3.0			3.0	-	-	1						
	Total:		**7.5**			**7.5**									
Total Assigned SCHs:			**19.0**		**6.0**	**25.0**									

Figure 4. Workload snapshot

The newly entered data is immediately reflected in the grid view (Figure *3*) and the fields are reset to their default values for the next assignment. Grid views are displayed below all web forms. For the teaching workload web form, grid view also provides the functionality of adding multiple labs and tutorials to an already assigned course. This is accomplished via a pop-up form using checkboxes thus avoiding repetitive entries for each section. The records are paginated, can be searched/sorted on any field, edited and deleted. When editing records from the grid view, same constraints are enforced to ensure data integrity. As a visual aid, the form continuously displays a list of courses which were offered in the previous year, but not yet assigned for the current year. Once the data entry is complete, a separate button pushes the data to the cube so that it is reflected in all reports. This feature prevents unnecessary processing of the cube while data is still being entered. The design allows concurrent users in which case simultaneous requests for cube processing are merged.

Similar web forms and grid views are available for entering new courses/faculty and modifying existing records. The need to modify courses arises from changes to title, credit hours and other characteristics. Similarly, changes to faculty information occurs upon promotion, tenure and changes to appointment type. In order to preserve data integrity, deletions of courses or faculty is not permitted if any associated records exist in the database. In other words, cascading deletions are not allowed. Instead, there is provision to render the courses and faculty as inactive so that they do not appear in any drop down menus, but remain available for historical reports.

Two additional web forms allow entering upcoming leaves and informal workload. Various types of leaves such as sabbatical, maternity, and paternal can be entered together with their status (tentative, approved, deferred, etc). This information is then displayed when Chairs assign the workload. Informal workload is recorded in a manner similar to a ledger – a faculty member can accrue, or be compensated, for work which is not directly related to teaching a course.

B. Reports

The key report which summarizes all information for a specific department is the Workload Snapshot (Figure 4). The report is segmented by appointment types and sessions. The workload of each instructor together with details such as sections, labs and tutorials is displayed in a single row (one row per instructor). The report is time-stamped for future reference. There are several other features of this snapshot:

- For faculty members with multiple affiliations, the workload assigned by the other department is shown in a different colour. This allows both departments to see the combined workload of the faculty member together with a distribution across various terms.
- Co-taught courses are marked with an asterisk which pops up the name of the other instructor with a simple mouse hover.
- For each instructor, this report displays the number of cross-listed courses assigned, course releases (if any),

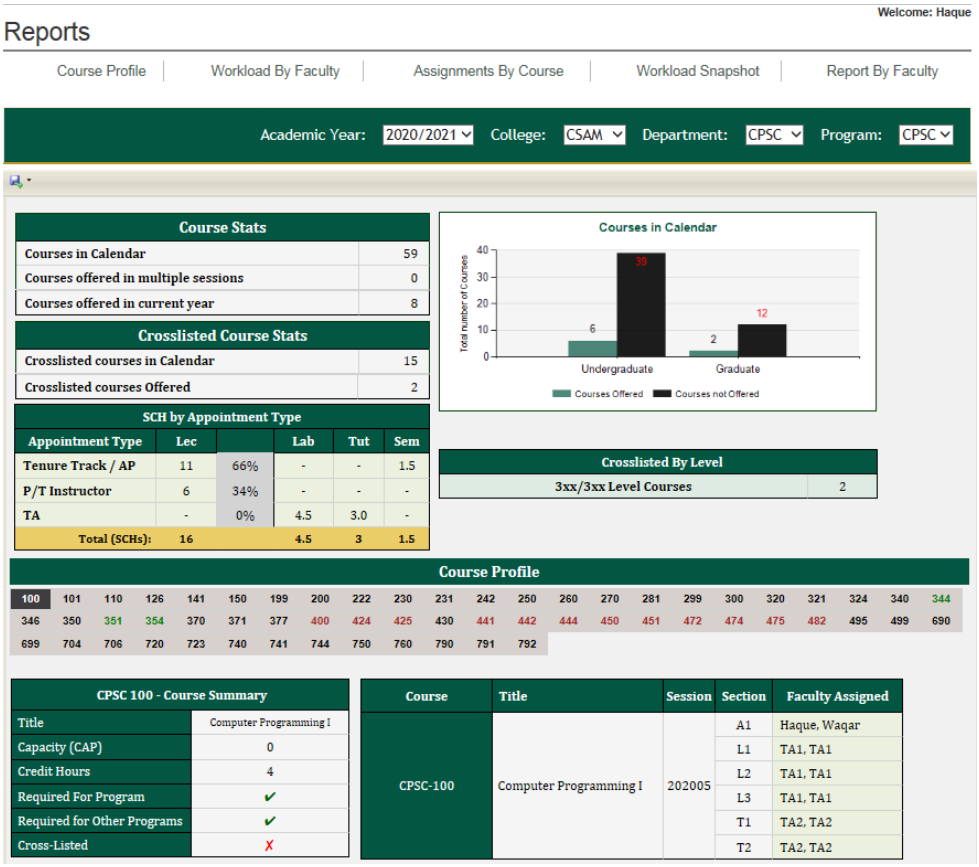


Figure 5. Course profile

number of new preparations and overload teaching (voluntary or paid).

- Number of distinct courses taught by the instructor is also displayed. Though multiple sections of a course and labs/tutorials of the same course count towards the workload, they do not count as distinct courses.
- Information icons are displayed, both for the instructor and courses. A mouse hover on these icons pops up additional information as entered in the comments section of web forms.
- Finally, it is possible to see the levels (undergraduate/ graduate) at which the instructor is teaching together with any specific comments such as reduced load, etc.

There are several additional reports which can be generated from this tab together with provisions to navigate to other drill-down and drill-through reports. Some of these reports are discussed below:

Course Profile. This report (Figure 5) provides summarized statistics for all courses in the calendar and those currently being offered by the department. It provides a further breakdown by cross-listed courses and offerings at the undergraduate and graduate level. The percentage of courses taught by full-time tenure track/tenured faculty versus others is also displayed. Course profiles for individual courses can be pulled from a drill-through report on the same page. The profile includes information such as whether the course is required, elective and/or cross-listed together with the current assignments, if any, for the course. A drill-down report provides the same information for the entire spectrum of courses giving an overall view at a glance. The list of courses is colour-coded to indicate whether a cross-listing exists within or across other departments. Other drill-down reports provide details at a finer granularity for the selected statistics. The reports can be generated for any academic year, but are limited by access control such that a Chairs can only view reports for their own designated department(s).

Workload by Faculty. This report (Figure 6) provides an individualized workload assignment for each faculty member in the department. This includes the term, course(s) assigned, course title and the total contact hours broken down by the sessions (fall, winter, spring, summer). Toggle buttons allow expansion of an individual's assignments. A very desirable feature on this report is the auto-generation of formal workload memo from the department chair to the instructor. The memo is produced in MS Word format, is editable and serves as the formal notification of the assignments in accordance with the Faculty Agreement. For instructor's affiliated with more than one department, an option is provided to generate the memo either for just the departmental assignments or for the entire workload of the faculty member.

Assignments by Faculty: CPSC
Academic Year: 2020/21

Appointment Type	Instructor		Term	Course	Course Title	Section	SCHs
P/T Instructor	⊞ TBA, TBA	Generate Memo (All Workload)			Total Assigned SCHs (TBA)		5.5
Tenure Track / AP	⊟ Haque, Waqar	Generate Memo (Department Only)	202005	CPSC-100 (Computer Programming I)	Computer Programming I	A1	3
				CPSC-499 (Special Topics)	Special Topics	A1	3
				CPSC-704 (Graduate Seminar in Computer Science)	Graduate Seminar in Computer Science	A1	1.5
				CPSC-706 (Topics in Computer Science Research)	Topics in Computer Science Research	A1	1.5
							9
			202101	CPSC-281 (Data Structures I)	Data Structures I	A1	3
							3
		Generate Memo (All Workload)			Total Assigned SCHs (Haque)		12
					Total Assigned SCHs (Program)		17.5

Figure 6. Workload by faculty

Assignments by Course. This report provides the workload from a different perspective, that is, by course numbers (Figure 7). For each course, the sections, labs, tutorials, capacity, session and instructor information is listed together. In addition, the preferred scheduling pattern for the course is also included. As stated earlier, direct access to institutional repositories was not available for this research, thus this report was found to be extremely useful. The administrative assistants used it for data entry into institutional scheduling software.

Assignments By Course: CPSC
Academic Year: 2020/21

CPSC Course Assignments

Course	Session	Instructor	Sec	CAP	SCH	Preferred Scheduling Pattern	Comments
CPSC-100 (Computer Programming I)	202005	Haque, Waqar	A1	60	3	2- 1.5-hour blocks	TA support for labs
CPSC-281 (Data Structures I)	202101	Haque, Waqar	A1	30	3	6:00 - 8:50pm	
COMM-353/CPSC-344 (Data Communications and Networking)	202101	Haque, Waqar	A1	-	3	-	
COMM-351/CPSC-351 (Management Information Systems)	202005	Haque, Waqar	A1	-	3	-	
CPSC-499 (Special Topics)	202005	TBA, TBA	A1	40	1	-	Fundamentals of BPM
CPSC-704 (Graduate Seminar in Computer Science)	202005	Haque, Waqar	A1	10	1.5	-	May switch with 100 Tut

Figure 7. Assignments by course

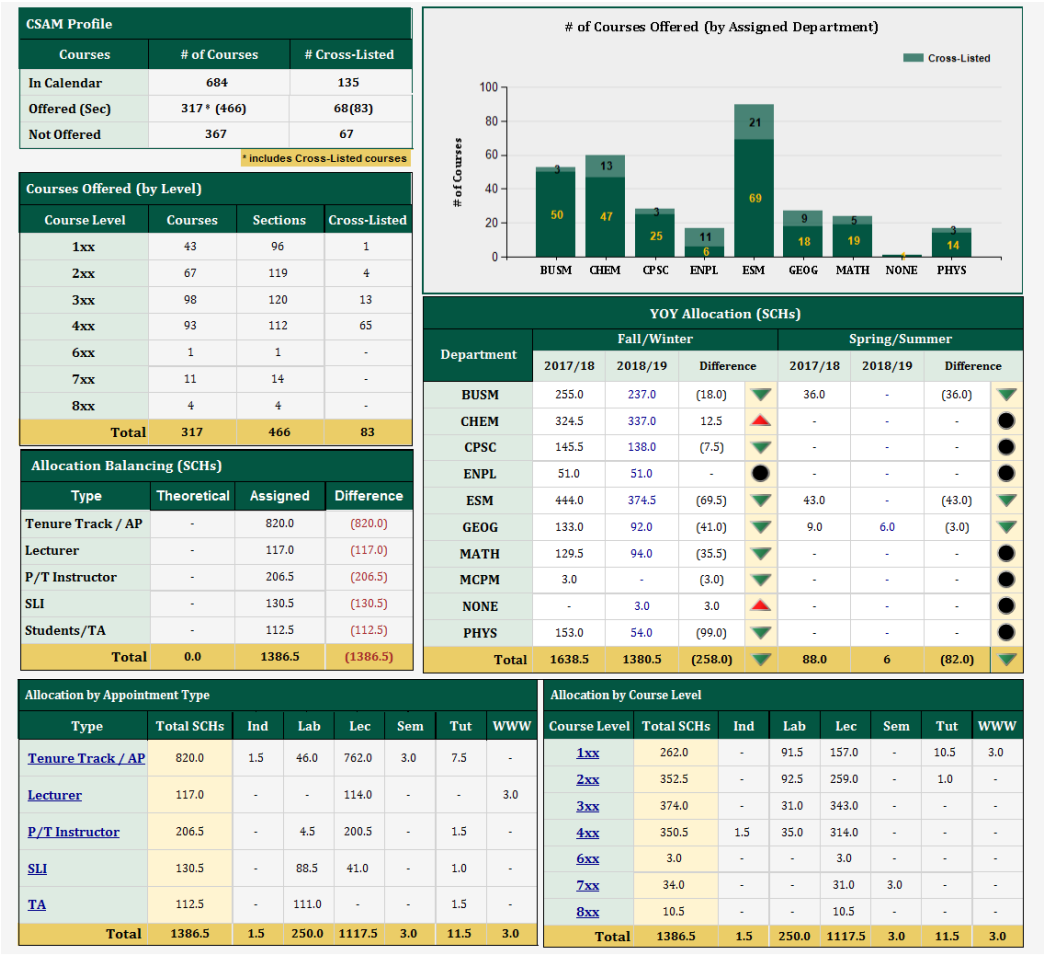
Report by Faculty. Besides providing the basic information entered for faculty, this report provides a historical perspective of all courses which have ever been taught by the faculty member. This cumulative information has been frequently pulled by administrative heads when engaging in workload consultations with the faculty.

Multi-year Course and Faculty Plan. Our framework allows data entry several years into the future. This helps with long-term planning both for courses and faculty. Generally, a rolling five-year plan is considered feasible. There is provision to select a start and end year so that the report can be generated for any period ranging from one to as many years as the data exists.

Other reports. A bird's eye view of the upcoming sabbatical leaves is one of the most powerful reports for the administrators. This allows for planning sabbatical coverages and can also be used to ensure that the leaves are not disruptive to the planned teaching schedule. Similarly, a report on tracking informal teaching workload allows the Chair to review when and how a faculty member accrued credit and when were they compensated. It should be noted that informal workload may differ across departments, could be discretionary, and may only be used as an unofficial record of member's activities. The design of the reporting module allows addition of new reports in a modular fashion.

C. Dean's Dashboard

The tentative workload assignments are completed by department chairs in consultation with faculty members. These are then forwarded to the Deans for formal approval after which official memos are issued. A problem often faced by the Dean is to sift through the plethora of spreadsheets each of which has a unique layout and contains information in non-standard formats. Often, this requires time-consuming consultations with Chairs to seek clarification. In our integrated framework, the Dean's



CSAM Profile

Courses	# of Courses	# Cross-Listed
In Calendar	684	135
Offered (Sec)	317 * (466)	68(83)
Not Offered	367	67

* includes Cross-Listed courses

Courses Offered (by Level)

Course Level	Courses	Sections	Cross-Listed
1xx	43	96	1
2xx	67	119	4
3xx	98	120	13
4xx	93	112	65
6xx	1	1	-
7xx	11	14	-
8xx	4	4	-
Total	317	466	83

Allocation Balancing (SCHs)

Type	Theoretical	Assigned	Difference
Tenure Track / AP	-	820.0	(820.0)
Lecturer	-	117.0	(117.0)
P/T Instructor	-	206.5	(206.5)
SLI	-	130.5	(130.5)
Students/TA	-	112.5	(112.5)
Total	0.0	1386.5	(1386.5)

YOY Allocation (SCHs)

Department	Fall/Winter 2017/18	Fall/Winter 2018/19	Fall/Winter Difference	Spring/Summer 2017/18	Spring/Summer 2018/19	Spring/Summer Difference
BUSM	255.0	237.0	(18.0)	36.0	-	(36.0)
CHEM	324.5	337.0	12.5	-	-	-
CPSC	145.5	138.0	(7.5)	-	-	-
ENPL	51.0	51.0	-	-	-	-
ESM	444.0	374.5	(69.5)	43.0	-	(43.0)
GEOG	133.0	92.0	(41.0)	9.0	6.0	(3.0)
MATH	129.5	94.0	(35.5)	-	-	-
MCPM	3.0	-	(3.0)	-	-	-
NONE	-	3.0	3.0	-	-	-
PHYS	153.0	54.0	(99.0)	-	-	-
Total	1638.5	1380.5	(258.0)	88.0	6	(82.0)

Allocation by Appointment Type

Type	Total SCHs	Ind	Lab	Lec	Sem	Tut	WWW
Tenure Track / AP	820.0	1.5	46.0	762.0	3.0	7.5	-
Lecturer	117.0	-	-	114.0	-	-	3.0
P/T Instructor	206.5	-	4.5	200.5	-	1.5	-
SLI	130.5	-	88.5	41.0	-	1.0	-
TA	112.5	-	111.0	-	-	1.5	-
Total	1386.5	1.5	250.0	1117.5	3.0	11.5	3.0

Allocation by Course Level

Course Level	Total SCHs	Ind	Lab	Lec	Sem	Tut	WWW
1xx	262.0	-	91.5	157.0	-	10.5	3.0
2xx	352.5	-	92.5	259.0	-	1.0	-
3xx	374.0	-	31.0	343.0	-	-	-
4xx	350.5	1.5	35.0	314.0	-	-	-
6xx	3.0	-	-	3.0	-	-	-
7xx	34.0	-	-	31.0	3.0	-	-
8xx	10.5	-	-	10.5	-	-	-
Total	1386.5	1.5	250.0	1117.5	3.0	11.5	3.0

Figure 8. Dean's dashboard

Dashboard (Figure 8) provides an aggregated view of the KPIs for the entire academic unit which consists of multiple departments and programs. Besides teaching workloads, this dashboard provides an overview of course distribution and allocation. The KPIs include the total number of courses offered (versus those in the calendar) together with a breakdown by levels, undergraduate/graduate courses, department and appointment types. In addition, courses offerings at each level are broken down by course classification such as lectures, seminars, labs, tutorials and mode of delivery (Independent study, WWW, etc.). A visual representation of year-over-year (YOY) change to the allocated semester contact hours for each academic term is also presented. An allocation report shows deviation, if any, from the allocated budgets. The reports displayed on this page can be drilled down for finer granularity.

This dashboard is currently only visible to the Dean for administrative reasons. Dean has also full access to other areas of the framework such as web forms and individual departmental reports. Once again, a key benefit is the standardized format of the reports which makes it easier to assess workload in a uniform manner and make informed executive decisions.

D. Admin

The primary purpose of this tab is to control access to the reports and web forms. The access control list is stored in the database thus making it independent of the Active Directory. This tab is only visible to super users who can add/edit access privileges, as necessary. While it is anticipated to be a rather uncommon activity, it is also possible to add new programs and departments under this tab. This allows for maintenance without seeking assistance from the IT department.

To conclude this section, we would like to mention some features which are common across all reports. For instance, tooltips are embedded in various sections of the reports to pop up more information with a simple mouse hover. Further, reports can be exported to a variety of formats such as MS Word, Excel, and pdf. This allows inclusion of teaching workload reports in other master documents. Due to large turnovers, sessional faculty including graduate students should be removed from dropdown lists and other areas of the application. The framework provides an option to render courses and instructors as inactive. However, in order to permanently remove these, all associated records must be deleted first. Cascading deletes have been suppressed to preserve historical information.

IV. CONCLUSION

We have proposed a framework for workload assignment that allows interactive allocation of teaching workload to faculty. In addition, a broader view of the courses offered and distribution across various levels is presented. The framework uses a combination of business intelligence techniques and web technologies to deliver the desired objectives. Data is entered through interactive web forms and validated instantly. The underlying hybrid OLAP cube allows use of relational stores as well as slicing of data along several dimensions to render reports in real-time. This combination of relational and multi-dimensional analytical processing reduces overhead significantly thus enhancing the overall performance. The data entered is immediately reflected in all reports within a matter of seconds. The end-to-end solution consists of validation and constraints embedded web forms which ensure data integrity. The dashboard not only provides analytical insights, but also auto-generates contractual memos. The framework has been successfully deployed and received positive feedback from various levels of management. The resulting standardized reporting has simplified the workload assignment process and resulted in more informed resource allocation. Though the primary objective of this work was to assist with management of teaching workload, a number of additional benefits have emerged. The administrators are able to visualize a number of course and faculty related metrics through various drill-down and drill-through reports. The modular solution allows for future extensions such as provision to migrate previous year's assignments and integration with institutional repositories. The framework presented can also be used as a template for other projects which can benefit from hybrid OLAP cubes.

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